DRSAR/SA/R-08

# COST/SCHEDULE UNCERTAINTY ANALYSIS OF THE XM1/ ALTERNATIVE ARMAMENT PROGRAMS

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JUNE 1976

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US ARMY ARMAMENT COMMAND

SYSTEMS ANALYSIS DIRECTORATE

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A comparison was made of development cost/schedule burdens incurred by adopting either the US 105mm, the UK 110mm or the FRG 120mm armament systems into the US XM-1 Tank Program. These comparisons were made in terms of schedule delays and additional cost to the XM-1 Program. Programs were developed to produce US guns/ammunition from FRG/UK technical data packages. Modifications to the XM-1 Program were structured to account for vehicle redesign phase to accept the FRG/UK systems. Cost and schedule estimates for each program, that

Block Number 20 - continued

is, US XM-1 with the US 105mm, the UK 110mm and the FRG 120mm armament systems, are presented and compared with the planned XM-1 105mm Program.

## PREFACE

The analyses described in this note were prepared as part of the Tripartite Tank Armament Study and the XM1 Tank Program Cost/Schedule Analysis. Although the analyses were completed, documented and distributed in the summer of 1975, its publication as a Systems Analysis Note was not accomplished until a year after the study due to higher priority concerns. The distinctions between the concepts considered in the study and the current status must be recognized.

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## INTRODUCTION

A determination will be made by US decision makers to adopt either the United Kingdom (UK) 110mm or the Federal Republic of Germany (FRG) 120mm armament system for the XM1 Tank or to continue with the current US 105mm armament system.

The objective of this report is to provide cost/schedule and technical risk information in support of the XM1 Tank Main Armament Decision.

An analysis was performed to compare the cost/schedule impacts of adopting the foreign systems with the official cost/schedule of the current XM1/105mm program. This analysis was published and is attached as US Cost/Schedule Uncertainty Analysis (see the Appendix). Potential cost overruns and schedule slippages of the current program are examined in this analysis, using the same procedures and guidelines as those described in the Appendix.

A description of the current XM1/US 105mm program is presented in the following section. The results of XM1/US 105mm analysis are then compared with programmed cost and the official XM1 schedule. These results are then compared with the cost/schedule estimates of the XM1/UK 110mm and XM1/FRG 120mm programs. The data for the XM1 program were furnished by the office of the XM1 Project Manager. Picatinny Arsenal furnished data on the XM735 projectile program.

## XM1/105mm PROGRAM

The network presented in Figure 1 traces the flow of XM1/US 105mm program activities from the armament decision to the initiation of full scale production. It shows the major activities required under the Army Materiel Acquisition Guidelines (AR 1000.1) and highlights critical activities of the XM1 program, e.g., contractor tests. In addition to the planned activities, the network also considers activities which could arise as a result of testing at DT/OT I, II, and III -- program termination and redesign/retest. Key milestones of the official XM1 Program presented in Table 1 are measured from the armament decision, October 1975.

Point and interval time-to-completion estimates were obtained for individual activities. Due to the difficulties of obtaining cost estimates for each activity, only cost overruns were computed. These can occur if a planned activity is not completed within the scheduled time or if unplanned activities are required (e.g., redesign/retest). Data Lists I and II present a description of the activities and their estimated time and cost overruns.

## RESULTS

The XM1/US 105mm program results, presented in Table 2, were

obtained for two sets of input data, differing only in regard to including or not including a Technical Transfusion activity. (Technical Transfusion is an unprogrammed activity which will occur or not occur--depending on an ASARC II/DSARC II decision. The purpose of Technical Transfusion is to incorporate the better components of both designs into the final design rather than select and build the design of one contractor.)

Schedule and cost results presented in Table 2 are increases over the planned schedule and programmed cost (Table 1). Upper (95%) and lower (5%) limits are presented, i.e., there is a 90% chance that the observed values will fall within these bounds.

In summary, the table shows that there is a 90% chance of a schedule slippage of 2 to 20 months in initiation of full production if a decision is made to incorporate Technical Transfusion. The expected slippage is about a year. If Technical Transfusion is not incorporated, then there is a 90% chance of a slippage of about 2 to 14 months in initiation of full production. The expected slippage is about one-half year. Expected cost increases are $59M and $10M, with and without Technical Transfusion, respectively. These estimates depend upon the availability of the XM735 projectile at DT/OT II. If production rounds are required, rather than engineering rounds, the program will be delayed an additional 4 to 6 months.

## ANALYSIS OF RESULTS

There are three primary decisions which can be made at each of the XM1 program reviews (ASARC/DSARD): continue with present design, redesign, or terminate the program. Program termination can occur due to a wide variety of events not related to a successful development program and was, therefore, not quantified in this analysis. The requirement for system redesign was included by obtaining estimates of the probability of a decision for redesign at each of the three ASARC/DSARC. There are, therefore, eight combinations of decision outcomes. These outcomes and the cost/schedule overruns resulting from each combination are presented in Table 3.

The first data line in Table 3 shows that if no major modifications are required, the expected program slippage is 4 months and the expected cost overrun is $2M. This combination of decisions is estimated to occur with about a 33% probability. If only Technical Transfusion is required, then the expected program slippage is 12 months with an expected cost overrun of $52.8M. This combination of decisions is estimated with a 38% probability. The other combinations are less likely to occur than either of the two discussed.

## XM1 PROGRAM COMPARISON

This section presents a side-by-side comparison of the cost/schedule results obtained for the three programs: XM1/US 105mm, XM1/UK 110mm, XM1/FRG 120mm. The first program will be referenced as the XM1

Current Program, the last two as the XM1 Alternative Programs. The data and results for the XM1 Alternative Programs used in the following sections were taken from the Appendix.

Table 4 summarizes the cost and schedule results for each of the three programs. The expected delays to the start of full production are 16 months for the UK 110mm system and 20 months for the FRG 120mm system; expected cost incurred is about $55M with either system. These delays and costs are caused by the additional redesign activities and uncertainties in adopting the foreign armament systems to the vehicle. The results of the XM1 Current Program analysis indicated a 7 month slippage due to vehicle related problems; the expected cost overrun is $10M (Technical Transfusion will add an additional 6 months).

The primary reason for the delays in the UK and FRG program is the 12-15 months required to redesign the vehicle to accept the heavier foreign armament after the armament decision. The redesign activities include contractor Engineering Design (ED) test being conducted simultaneously with prototypes production for DT/OT II. During this time period, the vehicle may or may not go through a Technical Transfusion activity, as indicated by the Current Program. Although the time required for Technical Transfusion is not significant, as the program is paced by the concurrent armament redesign activities, the cost will add $4M-$34M to the program.

From DT/OT II, both Alternative and Current Programs have identical activities. However, the data provided for these activities differ primarily due to the inclusion of vehicle uncertainties in the current program. The data for the Current Program contribute to greater schedule slippage and cost overruns than are caused by the foreign armament programs. This prompted us to obtain results from the viewpoint that the XM1 alternative armament programs will have at least the same level of uncertainty as the Current Program (i.e., time, cost, and probability levels) after the initiation of DT/OT II. These results are presented in Table 5.

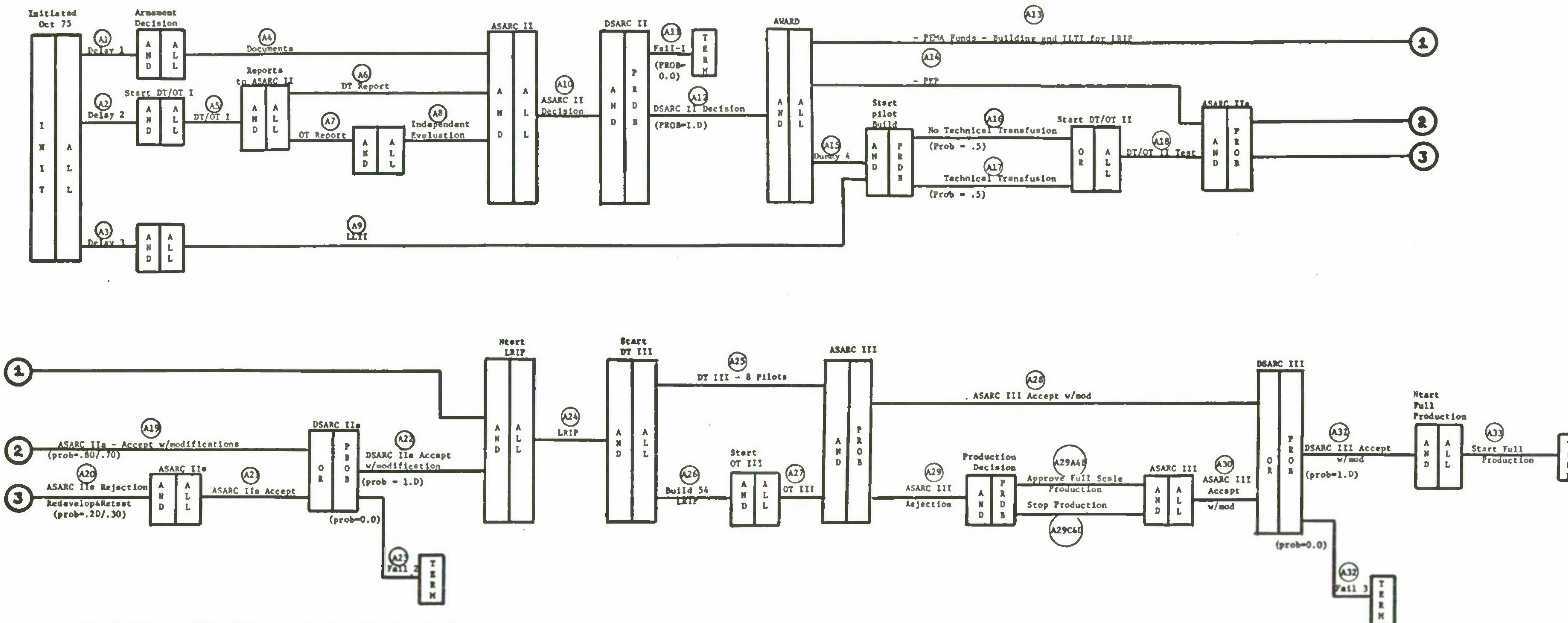
Assuming that the cost/schedule problems of the XM1 program are comparable in magnitude regardless of armament, then a 2 year delay, rather than a 1-1/2 year delay, is expected. An expected cost increase of about $70M, rather than $50M, was computed for the XM1 Alternative Program.

## SUMMARY

The published cost/schedule analysis in support of the Tripartite Tank Armament Study indicated a 1-1/2 year delay to full production at an expected cost increase of $55M (FY74) (measured from October 75 to initiation of full scale production) if either the UK 110mm or the FRG 120mm armament system is adopted into the XM1 Program. The analysis considered armament and armament/vehicle interface problems. The cost/schedule analysis performed on the XM1/US 105mm program indicated an

expected scheduled slippage of 1/2 year and an expected cost overrun of $10M (1 year and $59M with Technical Transfusion). This analysis considered uncertainties in time and cost attributed to vehicle development and production.

Assuming that the XM1/UK 110mm and FRG 120mm programs have levels of uncertainty (beyond DT/OT II) comparable to the XM1/US 105mm program, then the expected schedule delay for either foreign armament systems is 2 years with an expected cost increase of $71M.




**KEY**

INIT - Initiates program
AND - Input activities must be completed
ALL - All output activities are initiated
OR - At least one input activity must be completed
PROB - Initiates one activity based on probability of occurrence
TERM - Terminates network

Figure 1. XM1 Current Program

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TABLE 1. XM1/US 105mm SCHEDULE

(From Armament Decision - October 1975)

| Event (Start Of) | Scheduled Initiation (Mo/Date) |
|---|---|
| DT/OT II | 25 (Nov 77) |
| DT/OT III | 49 (Nov 79) |
| Full Production | 58 (Aug 80) |

DATA LIST I
XM1/CURRENT PROGRAM ACTIVITY DESCRIPTION

| NUMBER | NAME | PROBABILITY OF OCCURRING | DESCRIPTION |
|---|---|---|---|
| A1 | Delay-1 | 1.0 | Time delay to Armament Decision Selection is US 105mm |
| A2 | Delay-2 | 1.0 | Time delay to start DT/OT I on 1 Feb 75. |
| A3 | Delay-3 | 1.0 | Time Delay to 1 Jan 75 |
| A4 | Documents | 1.0 | Administrative work (e.g., RFP, D&F, SYS SPECS, DP, LCCE, RAM-D, DRA, COEA, Technical Task Force, Update - TOD, TOA, & BTA - Source Selection and PM negotiate.) |
| A5 | DT/OT I | 1.0 | Development Test and Operational Test 1 |
| A6 | DT I Report | 1.0 | Development Test Report to ASARC II |
| A7 | OT I Report | 1.0 | Operational Test Report to ASARC II |
| A8 | Independent Evaluation | 1.0 | Independent Evaluation Report to ASARC II |
| A9 | LLTI | 1.0 | Long Lead Time Items |
| A10 | ASARC II | 1.0* | ASARC II Decision |
| A11 | FAIL-1 | 0.0** | Terminate Program |
| A12 | DSARC II | 1.0* | DSARC II Decision |
| A13 | PEMA Funds | 1.0 | PEMA funds must be available to renovate buildings, purchase tooling and other long lead time items for low rate initial production. |

*Assumed to be 1.0
**Assumed to be 0.0

DATA LIST I (CONT)

| NUMBER | NAME | PROBABILITY OF OCCURRING | DESCRIPTION |
|---|---|---|---|
| A14 | PEP | 1.0 | Production Engineering & Planning. Supporting activity |
| A15 | Dummy-4 | 1.0 | Computer control arc |
| A16 | No Technical Transfusion | 0.5 | ASARC/DSARC II accepted system with minor modifications if needed. Prototype vehicles are built and delivered to DT/OT II. |
| A17 | Technical Transfusion | 0.5 | Major modification needed on vehicle system to continue program. Possible problem areas are: (1) Engine; (2) Fire control system; (3) Other (i.e., stored ammo load, armor design, coax, etc.). Major redesign and retesting must occur before prototypes are built and delivered to DT/OT II. |
| A18 | DT/OT II | 1.0 | Development and Operation Tests II. |
| A19 | ASARC IIa - acceptance | 0.8/0.7 | ASARC IIa acceptance of vehicle system with/without minor modifications. Probability of acceptance is 0.8 if there occurred a major Technical Transfusion after ASARC/DSARC II; Probability of acceptance is 0.7 otherwise. |
| A20 | ASARC IIa-Rejection | 0.2/0.3 | Major modifications needed for acceptance by ASARC/DSARC IIa. See A19 for probability levels. |
| A21 | Second ASARC IIa-Acceptance | 1.0* | Second ASARC IIa accepted vehicle after redesign efforts. |

*Assumed to be 1.0.

DATA LIST I (CONT)

| NUMBER | NAME | PROBABILITY OF OCCURRING | DESCRIPTION |
|---|---|---|---|
| A22 | DSARC IIa Acceptance | 1.0* | DSARC IIa acceptance decision. |
| A23 | FAIL-2 | 0.0** | Terminate program |
| A24 | LRIP | 1.0 | Low Rate Initial Production and delivery 8 pilots for DT/OT III. |
| A25 | DT III - 8 pilots | 1.0 | Development Test III. |
| A26 | Build 54 - LRIP | 1.0 | Production of 54 Vehicles for OT III. |
| A27 | OT III | 1.0 | Operational Test III. |
| A28 | ASARC III Acceptance | 0.95 | ASARC III acceptance for full production. |
| A29 | ASARC III Rejection | 0.05 | Major modifications are needed for ASARC III acceptance. |
| A29 A&B | Approve Full Scale Production | 0.2 | Full scale production will continue as scheduled with a retrofit program following. Probability of a fix in 6 months is 20%. Probability of a fix in 10 months is 80%. |
| A29 C&D | Stop Production | 0.8 | Full scale production is delayed until a fix is designed and tested. Probability of a 6 month slip is 20%. The probability of a 10 month slip is 80%. |
| A30 | Second ASARC II | 1.0* | Acceptance of vehicle full scale production. |
| A31 | DSARC III | 1.0* | DSARC III acceptance for full scale production. |
| A32 | FAIL-3 | 0.0** | Terminate program. |
| A33 | Start Full Scale Production | 1.0 | Full scale production of vehicle is started. |

*Assumed to be 1.0.

**Assumed to be 0.0.

DATA LIST II

XM1/CURRENT PROGRAM ACTIVITY TIME AND COST INFORMATION

| ACTIVITY | | | ACTIVITY COMPLETION TIMES | | | OVERRUN COST RATES (IF SCHEDULE IS EXCEEDED) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ESTIMATED TIME TO COMPLETION | | | | INCURRED COST ($M) | | | |
| Number | Name | SCHEDULED COMPLETION TIME | Min | Max | Most Likely | COST RATE ($M/MO) | Min | Max | Most Likely | FY |
| A1 | Delay-1 | 0 mo | 0 mo(50%)[a] | 4 mo | 2 mo | | | | | |
| A2 | Delay-2 | 4 mo | | 4 mo(constant) | | | | | | |
| A3 | Delay-3 | 3 mo | | 3 mo(constant) | | | | | | |
| A4 | Documents | 9 mo | | No Impact | | | | | | |
| A5 | DT/OT I | 3 mo | 3 mo(50%)[a] | 4.5 mo | 3 mo | 2.1<br>1.75 | | | | 76<br>74 |
| A6 | DT Report | 5 wk | 5 wk | 8 wk | 5 wk(80%)[a] | 2.1<br>1.75 | | | | 76<br>74 |
| A7 | OT Report | 2 wk | 2 wk | 3 wk | 2 wk | 2.1<br>1.75 | | | | 76<br>74 |
| A8 | Independent Evaluation | 4 wk | 4 wk | 5 wk | 4 wk | 2.1<br>1.75 | | | | 76<br>74 |
| A9 | LLTI | | | No Impact | | | | | | |
| A10 | ASARC II Decision | 0 | 2 wk | 4 wk | 2 wk(20%)[a] | 2.1<br>1.75 | | | | 76<br>74 |
| A11 | FAIL-1 | | | | | | | | | |

[a] A mo(B%) - B is the probability that the activity is completed in A.

DATA LIST II (CONT)

XM1/CURRENT PROGRAM ACTIVITY TIME AND COST INFORMATION

| ACTIVITY | | | ACTIVITY COMPLETION TIMES | | | OVERRUN COST RATES (IF SCHEDULE IS EXCEEDED) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCHEDULED | ESTIMATED TIME TO COMPLETION | | | COST RATE | INCURRED COST ($M) | | | |
| Number | Name | COMPLETION TIME | Min | Max | Most Likely | ($M/MO) | Min | Max | Most Likely | FY |
| A12 | DSARC II Decision | 0 | 0 mo | 1 mo | 2 wk | 2.1 | | | | 76 |
| | | | | | | 1.75 | | | | 74 |
| A13 | PEMA Funds | Supporting Activity | | Unknown | | | | | Unknown | |
| A14 | PEP | Supporting Activity | | No Impact | | | | | | |
| A15 | Delay-4 | | | Computer Control Arc | | | | | | |
| A16 | No Technical Transfusion | 16 mo | 15 mo(10%)[a] | 17 mo(30%)[a] | 16 mo* | 3.82 | | | | 78 |
| | | | | | | 2.84 | | | | 74 |
| A17 | Technical Transfusion | | 19 mo | 28 mo | 25 mo | 3.82 | | | | 78 |
| | | | | | | 2.84 | | | | 74 |
| | US Engine Change | | | | | 1.0 | | | 11.0 | 78 |
| | (Probability of occurance-.4) | | | | | 0.74 | | | 8.17 | 74 |
| | Fire Control Problems | | | | | 1.0 | | | 5.9 | 78 |
| | (Probability of occurance-.3) | | | | | 0.74 | | | 4.38 | 74 |
| | Other Major Problems | | | | | 1.0 | 2.0 | 4.0 | 3.0 | 78 |
| | (Probability of occurance-.3) | | | | | 0.74 | 1.49 | 2.97 | 2.23 | 74 |
| | Engineering Support for Multiple Problems | | | | | 1.0-2.4 | | | | 78 |
| | | | | | | 0.74-1.78 | | | | 74 |
| A18 | DT/OT II Test | 9 mo | 9 mo | 10 mo | 9 mo(80%)[a] | 0.6 | | | | 79 |
| | | | | | | 0.43 | | | | 74 |
| A19 | ASARC IIa Acc. | | 2 wk | 4 wk | 2 wk(20%)[a] | | | | | |

[a] A mo (B%) - B is the probability that the activity is completed in A.

DATA LIST II (CONT)

XM1/CURRENT PROGRAM ACTIVITY TIME AND COST INFORMATION

| ACTIVITY | | SCHEDULED | ACTIVITY COMPLETION TIMES | | | OVERRUN COST RATES (IF SCHEDULE IS EXCEEDED) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ESTIMATED TIME TO COMPLETION | | | COST RATE | INCURRED COST ($M) | | | |
| Number | Name | COMPLETION TIME | Min | Max | Most Likely | ($M/MO) | Min | Max | Most Likely | FY |
| A20 | ASARC IIa Rej. | | 6 mo | 12 mo | 10 mo(80%)[a] | 1.6<br>1.14 | 3.0 | 11.0 | 6.0 | 79<br>74 |
| A21 | Second ASARC IIa | | 2 wk(20%)* | 4 wk | 2 wk | 1.6<br>1.4 | | | | 79<br>74 |
| A22 | DSARC IIa | | 0 mo | 1 mo | 2 wk | | | | | |
| A23 | FAIL-2 | | | | | | | | | |
| A24 | LRIP | 15 mo | 14 mo | 15 mo | 15 mo(90%)[a] | | | | | |
| A25 | DT III Test | 9 mo | | 9 mo(constant) | | | | | | |
| A26 | 54 LRIP | 8 mo | | 8 mo(constant) | | | | | | |
| A27 | OT III Test | 1 mo | | 1 mo(constant) | | | | | | |
| A28 | ASARC III Acc. | | 2 wk | 4 wk | 2 wk(20%)[a] | | | | | |
| A29 | ASARC III Rej. | | 2 wk | 4 wk | 2 wk(20%)[a] | | | | | |
| A29 A&B | Continue Production | | 6 mo(20%)* | 10 mo(80%)[a] | | | 51.5(6 mo) | 76.5(10 mo) | | 74 |
| A29 C&D | Stop Production | | 6 mo(50%)* | 10 mo(50%)[a] | | | 49.0(6 mo) | 56.8(10 mo) | | 74 |
| A30 | Second ASARC III | | 2 wk | 4 wk | 2 wk(20%)[a] | | | | | |
| A31 | DSARC III | | 0 mo | 1 mo | 2 wk | | | | | |

[a]A month (B%) - B is the probability that the activity is completed in A.

DATA LIST II (CONT)

XMI/CURRENT PROGRAM ACTIVITY TIME AND COST INFORMATION

| ACTIVITY | | | ACTIVITY COMPLETION TIMES | | | OVERRUN COST RATES (IF SCHEDULE IS EXCEEDED) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | SCHEDULED | ESTIMATED TIME TO COMPLETION | | | COST RATE | INCURRED COST ($\bar{M}$) | | | |
| Number | Name | COMPLETION TIME | Min | Max | Most Likely | ($M/MO) | Min | Max | Most Likely | FY |
| A32 | FAIL-3 | | | | | | | | | |
| A33 | Start Full Scale Production | | Terminate Program | | | | | | | |

TABLE 2. XM1/US 105MM PROGRAM - SCHEDULE SLIPPAGE/COST INCREASE
(From Armament Decision to Full Production)

| Event (Start Of) | WITH TECHNICAL TRANSFUSION | | | | | | WITHOUT TECHNICAL TRANSFUSION | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Schedule Slippage (mo) | | | Cost Increase $\bar{M}$ FY74 | | | Schedule Slippage[a] (mo) | | | Cost Increase $\bar{M}$ FY74 | | |
| | 5% | Expected | 95% | 5% | Expected | 95% | 5% | Expected | 95% | 5% | Expected | 95% |
| DT/OT II | 4 | 9 | 11 | - | - | - | 0 | 1 | 2 | - | - | - |
| DT/OT III | 7 | 12 | 21 | - | - | - | 1 | 5 | 13 | - | - | - |
| FULL PRODUCTION | 8 | 13 | 23 | 23 | 59 | 95 | 2 | 7 | 14 | 0 | 10 | 49 |

[a] Add 6 months if XM735 production rounds are required at DT/OT II.

TABLE 3. XM1 CURRENT PROGRAM ANALYSIS

(From Armament Decision to Full Production)

| DECISION POINT | | | | SCHEDULE SLIPPAGE | | COST OVERRUN ($M FY 74) | |
|---|---|---|---|---|---|---|---|
| ASARC II | ASARC IIa | ASARC III | PROBABILITY OF OCCURRING | MEAN (MO) | 90% CONFIDENCE | MEAN | 90% CONFIDENCE |
| w/o TT | ACCEPT | ACCEPT | 33.3% | 4 | ±2 | 2.8 | ± 2.0 |
| w TT | ACCEPT | ACCEPT | 38% | 12 | ±3 | 52.8 | ±20.0 |
| w/o TT | MMR | ACCEPT | 14.3% | 14 | ±2 | 19.6 | ± 4.0 |
| w/o TT | ACCEPT | MMR | 1.7% | 7 | ±4 | 70.8 | ±16.0 |
| w TT | MMR | ACCEPT | 9.5% | 21 | ±4 | 69.5 | ±25.0 |
| w TT | ACCEPT | MMR | 2.0% | 15 | ±6 | 121.6 | ±30.0 |
| w/o TT | MMR | MMR | 0.7% | 17 | ±5 | 87.9 | ±20.0 |
| w TT | MMR | MMR | 0.5% | 25 | ±7 | 138.5 | ±35.0 |

w/o TT - without Technical Transfusion
w TT - with Technical Transfusion
ACCEPT - No Modifications Required
MMR - Major Modifications Required

TABLE 4. XM1 PROGRAMS - EXPECTED SCHEDULE SLIPPAGE AND COST INCREASE[a]

(From Armament Decision to Full Production)

| Program Alternative | Schedule Slippage | | | Cost Increase ($$\bar{M}$ FY 74) | | |
|---|---|---|---|---|---|---|
| | 5% | Expected | 95% | 5% | Expected | 95% |
| XM1/US 105mm | 2 | 7 | 14 | 0 | 10 | 49 |
| XM1/UK 110mm | 11 | 16 | 21 | 48 | 54 | 63 |
| XM1/FRG 120mm | 14 | 20 | 27 | 48 | 55 | 63 |

[a]Does not include Technical Transfusion.

TABLE 5. XM1 PROGRAMS - EXPECTED SCHEDULE SLIPPAGE AND COST INCREASE TO FULL PRODUCTION[a]

(From Armament Decision to Full Production)

| ARMAMENT | SCHEDULE DELAY (MO) | | COST INCREASE ($MFY74) | |
|---|---|---|---|---|
| | Expected | 90% PI | Expected | 90% PI |
| US 105mm | 7 | $\pm$ 6 | 10 | $\pm$ 15 |
| UK 110mm | 22 | $\pm$ 9 | 71 | $\pm$ 40 |
| FRG 120mm | 25 | $\pm$10 | 71 | $\pm$ 41 |

[a]Assumes Comparable uncertainties for XM1 System regardless of armament. Does not include Technical Transfusion.

# APPENDIX

## US COST/SCHEDULE UNCERTAINTY ANALYSIS

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## Section I. Gun/Ammunition in Isolation

### OBJECTIVE

The objective of this analysis is to provide a comparison of cost and schedule burdens incurred by adopting each of the candidate armament systems.

### INTRODUCTION

This section supports the following Measures and Indicators of Burden:

A.9 - Gun/Ammo development and production schedules, including uncertainty.

A.10 - Time phased life cycle cost of gun/ammo, including uncertainty.

As agreed, network* techniques were utilized to insure a common format for comparing and discussing national programs and to have a convenient format for the statistical procedures required for the uncertainty analysis.

The analysis presents a comparison of the current XM735 ammunition program with the gun/ammunition programs resulting from the decision to use the FRG or UK candidate armament. These programs show the cost and schedules of the engineering and test activities required to convert the FRG/UK technical data packages** (TDP) into US TDP's and to enter into full production. Major engineering and testing activities are considered from receipt of the TDP until initiation of full production.

### APPROACH

Separate analyses were conducted for the cannon, shell metal parts, and propellant by those arsenals with mission responsibilities in these

*A network is a graphic representation of a program in which activities and decision points/milestones are interrelated according to sequence or concurrence.

**The technical data package should consist of (1) detailed component and assembly drawings with necessary notes to identify special requirements for manufacture and assembly, (2) material specifications and mechanical properties, and (3) specifications giving the inspection requirements and ballistic test requirements. Description of manufacture for special and/or unusual processes should be included.

The technical data package must reflect the ammunition submitted for performance and safety evaluation. The ammunition, in turn, must have demonstrated acceptable performance and have been accepted by the developing country for production initiation.

areas: Watervliet, Frankford, and Picatinny. The following guidelines were used for conducting these analyses:

a. The networks would be initiated at receipt of the technical data package and terminated at initiation of full production.

b. Off-shore hardware would be available for comparison purposes.

c. Each arsenal would select one of the standard network analyzer computer techniques.

d. Every effort would be made to obtain empirical data.

e. Triangular distributions would be used to initially quantify subjective schedule uncertainty. (Estimates of the minimum, maximum, and most likely values would be used to define the distributions.)

f. Cost uncertainty representation would be tailored to the activity. Cost dependence on activity time would be described if applicable, e.g.,

$$\text{Cost} = a + rt, \quad a,\ r \text{ fixed}$$

$$\text{Cost} = A + rt, \quad \begin{array}{l} A, \text{ random} \\ r, \text{ fixed} \end{array}$$

$$\text{Cost} = A + Rt, \quad A,\ R \text{ random}$$

The triangular distribution would be used for the random variables.

Although the standard network analyzers differ in certain respects, they are alike in those considerations pertinent to this study. With regard to network format:

a. The lines (arcs) of the network are used to represent activities which consume time (e.g., testing) or carry information (e.g., test successfully completed).

b. The boxes (nodes) of the network are used to represent milestones (e.g., initiation and termination of activities, decision points.) Logic features are contained in the nodes for the input and output arcs (e.g., "AND" input logic requires all input arcs to be completed before the output arcs are initiated. "PROB" output logic initiates one of several output arcs according to specified probabilities).

Minimum, maximum, and most likely estimates were obtained for cost and schedule data on those activities where uncertainty exists. In addition, a cost and time relationship was specified to account for cost increases due to slipped schedules, where applicable.

An iteration consists of statistically tracing the program flow and cumulating cost and time. Several hundred iterations were used to

obtain the cost/schedule mean values and confidence limits presented in this report.

The cannon, shell metal parts, and propellant networks were interfaced to obtain the armament cost/schedule for the UK and FRG candidates. Consideration was given to the situation that not all technical problems are resolvable by the expenditures of cost and time resources. Repeated or significant failures would lead to an early termination of the proposed program. The US candidate 105mm cannon is a production item and, therefore, not addressed.

ANALYSIS OF UK/FRG ARMAMENT SYSTEMS

The cannon, shell metal parts, propellant networks, data, and results are presented in Annexes A, B, and C, respectively. Differences between the networks representing the programs for the two rounds are minor; for example, additional time is incurred in translating the FRG technical data package into English. However, some schedule/cost differences were observed.

The networks indicate how the projects interface, e.g., Watervliet Arsenal must provide cannons for later Picatinny and Frankford Arsenal tests, while off-shore cannons will be used for early tests; the shell metal parts network (Frankford) is a subset of the propellant/load-and-pack network (Picatinny).

Assumptions on the availability of FRG or UK hardware were made for the analysis. The validity of these assumptions are crucial to the following schedule/cost estimates:

a. The estimated time from armament decision to receipt of the technical data package (TDP) is two to six months.

b. One FRG serviceable cannon will be available within the US four months from receipt of the TDP. One UK serviceable cannon will be available within six months from receipt of TDP. Another cannon will be available ten months after receipt of the TDP. (These requirements are described in Annexes A and B.)

c. FRG Ammunition will be available six months after receipt of the TDP; UK ammunition will be available four months after receipt of the TDP.

Four milestones are presented as follows:

a. XM1 System Test (DT/OT II), i.e., availability of hardware for DT/OT II acceptance testing of the XM1 System.

b. Complete Development, i.e., completion of the US Technical Data Package.

c. XM1 System Test (DT/OT III), i.e., availability of hardware for

DT/OT III acceptance testing of the XM1 System. Ammunition for DT/OT III will be produced prior to the start of DT/OT II and is not considered a critical interface point.

d. Full Production, i.e., the availability of first full production items. Cost of ammunition test rounds is included in total ammunition cost.

RESULTS

In Table A-1, the expected values of time and cost are displayed, together with 90% probability interval (PI)*, for the UK 110mm and FRG 120mm gun/ammunition systems. These values reflect development schedules and costs from the armament decision.

The expected times and 90% PI for the UK gun and ammunition systems to initiation of full production are 71 ± 5 months and 62 ± 6 months, respectively. Similarly, the cost of the gun is \$6.2M ± \$0.2M and the cost of the ammunition is \$9.1M ± \$1.1M.

The expected times and 90% PI for the FRG gun and ammunition systems to initiation of full production are 70 ± 3 months and 66 ± 8 months, respectively. Similarly, the FRG gun cost is \$6.7M ± \$0.2M; the ammunition cost is \$9.1M ± \$1.1M.

The ammunition schedule results are applicable to both KE and CE projectiles. The cost results apply to the KE round and include development costs and rounds for the XM1 program (\$2.8M). CE development costs were estimated to be \$4.8M and \$5.0M for the UK and FRG rounds, respectively; CE rounds for the XM1 program were estimated to cost \$1.6M.

The probability of completing a successful development program is greater than 0.85 for either UK or FRG gun/ammunition systems.

*Ninety percent of the values (cost/time) observed in the thousand iterations of the networks were contained between the upper (95%) and lower (5%) values.

TABLE A-1. CANDIDATE ARMAMENT COST/SCHEDULE COMPARISON ANALYSES

(From Receipt of Technical Data Package to Specified Milestone)

| | Schedule (Mo) | | | Cost ($M̄) | | |
|---|---|---|---|---|---|---|
| Candidate Armament<br>Subsystems<br>Milestones | 5%[a] | Expected | 95%[b] | 5%[a] | Expected | 95%[b] |
| US - 105mm | | | | | | |
| Gun | | | | | | |
| Ammo (XM735) | | | | | | |
| XM1 System Test (DT/OT II) | | 25 | | | | |
| Full Production | | 33 | | | 1.6 | |
| UK - 110mm | | | | | | |
| Gun | | | | | | |
| XM1 System Test (DT/OT II) | 24 | 29 | 34 | | | |
| Complete Development | 37 | 42 | 47 | | | |
| XM1 System Test (DT/OT III) | 60 | 65 | 70 | | | |
| Full Production | 66 | 71 | 76 | 6.0 | 6.2 | 6.4 |
| Ammo (KE)[c] | | | | | | |
| XM1 System Test (DT/OT II)[d] | 29 | 33 | 37 | | | |
| Complete Development | 36 | 40 | 44 | | | |
| XM1 System Test (DT/OT III)[d] | - | - | - | | | |
| Full Production | 58 | 62 | 68 | 8.0 | 9.1 | 10.2 |
| FRG - 120mm | | | | | | |
| Gun | | | | | | |
| Tank System Test (DT/OT II) | 26 | 28 | 30 | | | |
| Complete Development | 38 | 40 | 42 | | | |
| XM1 System Test (DT/OT III) | 61 | 64 | 67 | | | |
| Full Production | 67 | 70 | 73 | 6.5 | 6.7 | 6.9 |
| Ammo (KE)[c] | | | | | | |
| XM1 System Test (DT/OT II)[d] | 31 | 37 | 43 | | | |
| Complete Development | 40 | 44 | 48 | | | |
| XM1 System Test (DT/OT III)[d] | - | - | - | | | |
| Full Production | 58 | 66 | 74 | 8.0 | 9.1 | 10.2 |

[a]There is a 5% chance that the value will be less than displayed value.

[b]There is a 95% chance that the value will be less than displayed value.

[c]For CE (HEAT) Round the schedule is the same, development cost is $4.8M̄ for the UK 110 and $5.0M̄ for the FRG 120. CE hardware cost for XM1 test is $1.6M.

[d]Tank System Test Hardware - Hardware is available for tank system acceptance test DT/OT II and DT/OT III. Rounds for DT/OT III will be available from DT/OT II production. XM1 test cost is included in this analysis ($2.8M̄).

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## Section II. Vehicle Development Including Gun Ammunition

### OBJECTIVE

The object of this analysis is to compare the cost/schedule burdens incurred by the XM1 Tank System by selection of each candidate armament.

### INTRODUCTION

This section supports the following Measures and Indicators of Burdens:

B.1 - Time phase life cycle cost, including uncertainty estimates.

B.2 - Vehicle development and production schedules, including uncertainty estimates.

The network procedures and guidelines described in the US Gun/Ammo Cost/Schedule Uncertainty Analysis were used for this analysis. This paper compares the current XM1 program schedule and cost with an XM1 program modified to incorporate the alternate armaments. The information obtained in the US Gun/Ammo Cost/Schedule Uncertainty Analysis (Section I) was input to this study. Uncertainty information (minimum, maximum, and most likely values) was estimated for the XM1 activities and was interfaced with the gun/ammo estimates to produce cost/schedule distributions of time-to-full production and cost-to-full production.

### ANALYSIS

<u>Current Program - XM1/XM735</u>.

Table A-2 presents the current XM1/105mm schedule for selected key milestones. The cost of the program for the period from September 1975 to initiation of full production was not addressed in this analysis.

<u>XM1/Alternative Armament Program</u>.

Figure A-1 presents a network for the modified XM1 program to accommodate vehicle redesign and the alternative gun/ammo development programs. Data Lists A-I and A-II present a description of those activities and estimated program cost deviations from the Current Program.

This modified program differs from the current XM1 program in the following two respects.

1. Following the armament decision, the vehicle will undergo a major redesign phase to accommodate the heavier foreign armament. The contractor, after redesigning and building three prototypes, is given time to perform Engineering Design (ED) tests. Deficiencies

are corrected while pilot build (8 pilots) is continued. DT/OT II is then initiated and conducted in a similar manner to the original XM1 program.

2. The gun/ammunition programs are added. The network shows the critical gun/ammunition and vehicle interfaces: (a) at the start of DT/OT II, (b) at the start of DT/OT III, and (c) at the start of full production. Ammunition, guns, and vehicles must be available at these points with the appropriate lead time and stage of development and in the required quantities or program delays will result.

The assumption was made that the gun and ammunition technical data packages (TDPs) would be available within the same time period. Receipt of the TDPs is critical to the XM1 schedule as completion of these arcs initiates the US Gun/Ammo Development Programs. Initial estimates are that these packages would be available from 2 to 4 months after armament decision -- with 3 months as the most likely value. The armament decision was estimated to occur at the end of September 1975 at the earliest, but no later than the end of November 1975.

RESULTS

Results were obtained for three XM1 program milestones:

a. DT/OT II (acceptance test). The engineering and development tests required for the XM1 gun/ammo system to start Low Rate Initial Production.

b. DT/OT III (acceptance test). The development and operational test required for initiation of full production.

c. Full Production. Simultaneous full scale production of ammunition, guns, and vehicles.

The ammunition, KE/CE (HEAT), development program interfaces with the XM1 program at DT/OT II and the start of full production. No interface occurred at DT/OT III as engineering rounds would be available in advance of the milestone. The cannon development program interfaces with the XM1 program at DT/OT II, DT/OT III, and initiation of full scale production.

The XM1 Alternative Armament Program cost and schedule deviations from the XM1/105mm current schedule are presented in Table A-3. The expected values of time and cost are displayed, together, with a 90% probability interval*. The cost/schedule deviations are those incurred from September 1975 to initiation of full production and includes the

*Ninety percent of the values (cost/time) observed in the thousand iterations of the networks were contained between the upper (95%) and lower (.05%) values.

vehicle program, the cannon and ammunition (KE and CE) development programs, and cannon and ammunition hardware for the XM1 tests. The estimated delay and 90% probability interval to DT/OT II is 14 ± 4 months for the UK 110mm system and 18 ± 7 months for the FRG 120mm system. The estimated delay to DT/OT III and initiation of full scale production is 16 months for the UK 110mm system and 20 months for the FRG 120mm system with a ± 5 month 90% probability interval. The expected total cost increase and 90% probability interval incurred by the dedision to adopt either the UK 110mm or FRG 120mm armament system is $54.6 ± 8M.

A major factor in the schedule delays is the timely availability of US-produced safety certified ammunition at DT/OT II. A schedule analysis was conducted assuming off-shore ammunition could be obtained for this test; the results are presented in Table A-4. The estimated delay and 90% probability interval to DT/OT II is 11 ± 2 months for UK or FRG systems. The delay to DT/OT III and initiation of full production is 14 ± 4 months for the UK 110mm system and 13 ± 3 months for the FRG 120mm system; the small difference observed is due to an estimated difference in the cannon development programs. Ammunition availability and cost for this alternative was not assessed. The expected time delay for the vehicle program in isolation is 13 ± 3 months.

TABLE A-2. CURRENT XM1/105mm ARMAMENT SCHEDULE

| EVENT (Start of) | SCHEDULED INITIATION (Mo/Date) |
|---|---|
| DT/OT II | 25 (Nov 77) |
| DT/OT III | 49 (Oct 79) |
| Full Production | 58 (Aug 80) |

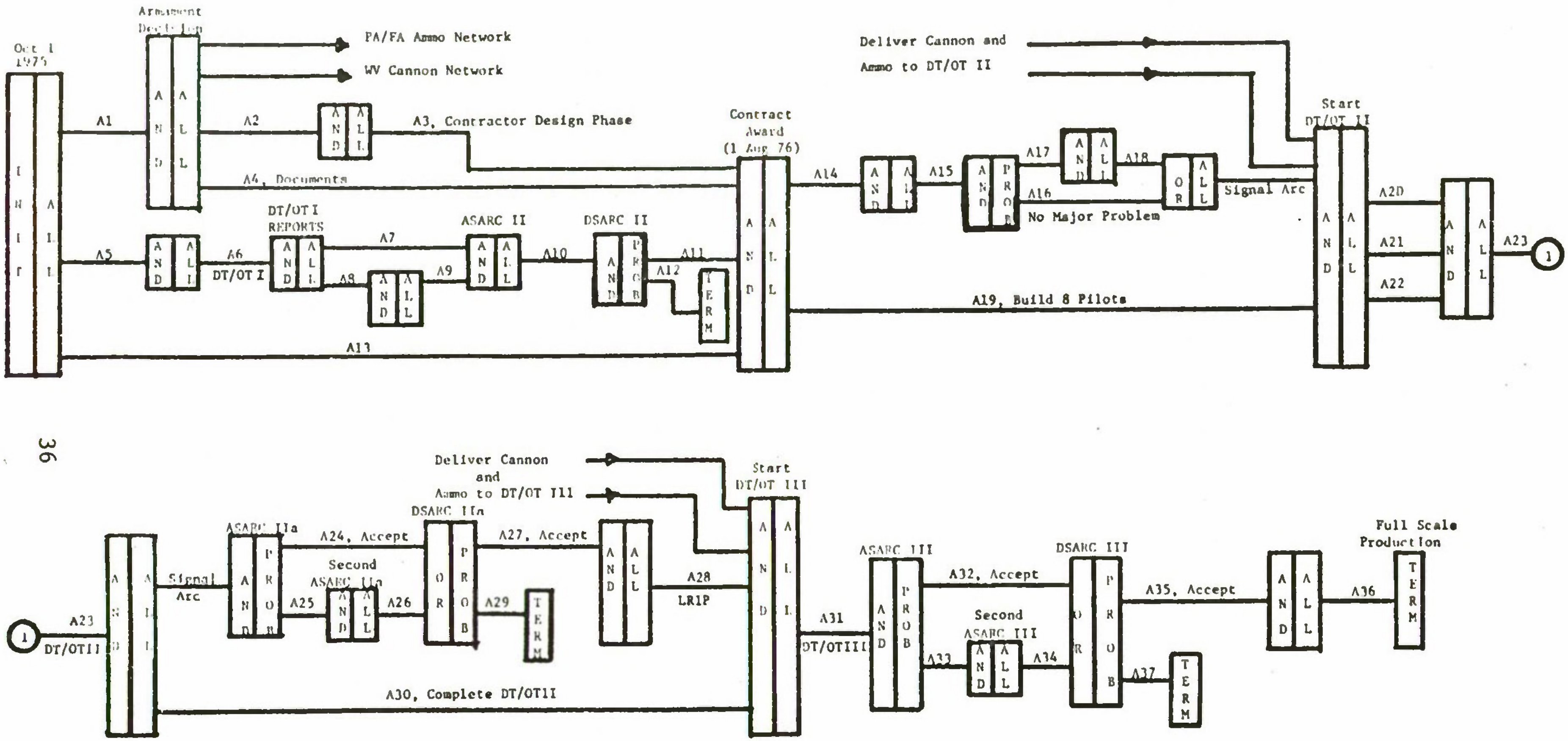


Figure A-1. XM1 Tank Program with Alternative Weapon System

DATA LIST A-I

XM1/ALTERNATIVE PROGRAM ACTIVITY DESCRIPTION

| ARC NUMBER | NAME | PROBABILITY OF OCCURRING | DESCRIPTION |
|---|---|---|---|
| A1 | Delay - 1 | 1.0 | Time delay to armament decision |
| A2 | Contractor Rev. Lead Time | 1.0 | Administrative Lead Time |
| A3 | Contractors (2) Initiate Design Revision | 1.0 | Begin Baseline Design Revision |
| A4 | Documents | 1.0 | Administrative Work (i.e., RFP, D&F, Sys Specs, DT, LCC, RAM-D, DRA, COEA, TSSG, Update TOD, BTA and Source Selection and PM Contract Negotiate |
| A5 | Delay - 2 | 1.0 | Time delay to start DT/OT I on 1 Feb 75 |
| A6 | DT/OT I | 1.0 | Development and Operational Test I |
| A7 | DT I Report | 1.0 | Development Test Report to ASARC II |
| A8 | OT I Report | 1.0 | Operational Test Report to ASARC II |
| A9 | Independent Evaluation | 1.0 | Independent Report to ASARC II |
| A10 | ASARC II Decision | 1.0 | ASARC II Decision |
| A11 | DSARC II Decision | 1.0 | DSARC II Decision |
| A12 | Fail | 0.0 | Terminate Program |
| A13 | LLTI | 1.0 | Long Lead Time Items |
| A14 | Design Build, 3 pilots | 1.0 | Design/Build 3 pilots for contractor test |

DATA LIST A-I (CONT)

| ARC NUMBER | NAME | PROBABILITY OF OCCURRING | DESCRIPTION |
|---|---|---|---|
| A15 | Contractor ED Test | 1.0 | Contractor ED Test, 3 Pilots |
| A16 | No Major Prob/Complete Test | 0.9 | No major problems, contractor ED Test completed |
| A17 | Major Prob | 0.1 | Major problem uncovered |
| A18 | Redesign/Retest | 1.0 | Problem corrected, remainder of Contractor ED Test completed |
| A19 | Begin build, 8 pilots (deliver 2) | 1.0 | Begin build of 8 pilots, 2 delivered for start of DT/OT II. |
| A20 | Refurbish, deliver 3 pilots | 1.0 | Refurbish 3 contractor pilots and deliver for DT/OT II |
| A21 | Deliver 6 pilots | 1.0 | Complete delivery of 6 pilots for DT/OT II |
| A22 | DT/OT II Buildup | 1.0 | DT/OT II started with 2 pilots, 9 remaining pilots delivered. |
| A23 | DT/OT II Full Fleet | 1.0 | Continue DT/OT II with 11 pilots |
| A24 | Accept w/Minor Mods | 0.95 | ASARC IIa acceptance of vehicle system with/without minor modifications. |
| A25 | Reject, Redevelop, Retest | 0.05 | ASARC IIa rejection, major modification and retesting needed for acceptance. |
| A26 | DSARC IIa Prep | 1.0 | Preparation time for DSARC IIa |
| A27 | Accept | 1.0 | DSARC IIa Acceptance Decision |

DATA LIST A-I (CONT)

| ARC NUMBER | NAME | PROBABILITY OF OCCURRING | DESCRIPTION |
|---|---|---|---|
| A28 | Pre-Rolloff LRIP | 1.0 | Initiate Low Rate Initial Production |
| A29 | Fail | 0.0 | Terminate program |
| A30 | Complete DT II | 1.0 | DT II Completion, independent of acceptance/rejection at ASARC IIa. |
| A31 | Test 62 vehicles | 1.0 | Initiate testing (8 pilots for DT III, and 54 pilots for OT III) |
| A32 | Accept w/Minor Mods | 0.99 | ASARC III acceptance of vehicle system with/without minor modifications |
| A33 | Reject, redevelop, retest apply mods | 0.01 | ASARC III rejection, major modification and retesting needed for acceptance |
| A34 | DSARC III Prep | 1.0 | Preparation time for DSARC III |
| A35 | Accept | 1.0 | DSARC III Acceptance Decision |
| A36 | Start Full Prod | 1.0 | Full Scale Vehicle Production Initiated |
| A37 | Fail | 0.0 | Terminate program |

DATA LIST A-II

XM1/ALTERNATE PROGRAM
ACTIVITY TIME AND COST RATE INFORMATION

ACTIVITY COMPLETION TIMES

| ARC NUMBER | MIN ($t_1$) | MAX ($t_3$) | MOST LIKELY ($t_2$) | COST RATE $/MO |
|---|---|---|---|---|
| A1 | 0 | 3 | 0 | 0.12 |
| A2 | 3 | 4 | 3 | 0.12 |
| A3 | | | 1 Aug 76 | 0.12 |
| A4 | | | 1 Aug 76 | |
| A5 | | | 1 Feb 76 | |
| A6 | | | 3 | |
| A7 | | | 2 | |
| A8 | | | 1 | |
| A9 | | | 1 | |
| A10 | | | 1 Jul 76 | |
| A11 | | | 1 Aug 76 | |
| A12 | | | 0 | |
| A13 | | | 1 Aug 76 | |
| A14 | 16 | 19 | 18 | 2.3(t-15 Mo) |
| A15 | | | 5 | 2.3 |
| A16 | 3 | 4 | 3 | 2.3 |
| A17 | | | 0 | |
| A18 | 4 | 10 | 6 | 2.3 |
| A19 | | | 24 | |
| A20 | 4 | 5 | 5 | 0.2 |
| A21 | 4 | 5 | 5 | |

DATA LIST A-II (Cont)

ACTIVITY COMPLETION TIMES

| ARC NUMBER | MIN ($t_1$) | MAX ($t_3$) | MOST LIKELY ($t_2$) | COST RATE $/MO |
|---|---|---|---|---|
| A22 | | | 5 | |
| A23 | | | 4 | |
| A24 | | | 1 | |
| A25 | 4 | 10 | 6 | 1.45 |
| A26 | | | 1 | |
| A27 | | | 0 | |
| A28 | | | 15 | |
| A29 | | | 0 | |
| A30 | | | 6 | |
| A31 | | | 8 | |
| A32 | | | 1 | |
| A33 | 6 | 12 | 10 | |
| A34 | | | 1 | |
| A35 | | | 0 | |
| A36 | | | 0 | |

ACTIVITY COSTS ($\$\overline{M}$)

| ARC NUMBER | MIN ($c_1$) | MAX ($c_2$) | MOST LIKELY ($c_3$) |
|---|---|---|---|
| A14 | 0.4 | 0.4 | 0.4 |
| A18 | 2.0 (.5)[a] | 5.0-9.0 (.1)[b] | 2.0-5.0 (.4)[b] |
| A25 | 1.0 (.5)[a] | 3.0-5.0 (.1)[b] | 1.0-3.0 (.4)[b] |
| A33 | 22.0 | 59.0 | 46.0 |

[a] A(B%), B is the probability that activity cost will be A

[b] A-B(c), c is the probability that activity cost will be between A and B. In this range all values are equally likely.

TABLE A-3. XM1/ALTERNATIVE ARMAMENT COST/SCHEDULE COMPARISON

| EVENT (Start Of) | Δ SCHEDULE[a] (Mo) 5% | Expected | 95% | Δ COST ($M) 5% | Expected | 95% |
|---|---|---|---|---|---|---|
| FRG - 120mm gun/ammo[b] | | | | | | |
| DT/OT II | 12 | 18 | 25 | -- | -- | -- |
| DT/OT III | 14 | 20 | 27 | -- | -- | -- |
| Full Production | 14 | 20 | 27 | 47.9 | 54.7 | 63.3 |
| UK - 110mm gun/ammo[b] | | | | | | |
| DT/OT II | 10 | 14 | 18 | -- | -- | -- |
| DT/OT III | 11 | 16 | 21 | -- | -- | -- |
| Full Production | 11 | 16 | 21 | 47.7 | 54.5 | 63.1 |

[a]Schedule and cost values represent increases (Δ) in cost and time over the current XM1/105mm program.

[b]For KE and CE rounds only.

TABLE A-4. XM1/ALTERNATIVE ARMAMENT COST/SCHEDULE COMPARISON (Assuming Ammo Does Not Delay DT/OT II)

| EVENT (Start Of) | FRG 120mm Gun/Ammo[a] Δ SCHEDULE[b] (Mo) 5% | Expected | 95% | UK 110mm Gun/Ammo[a] Δ SCHEDULE[b] (Mo) 5% | Expected | 95% |
|---|---|---|---|---|---|---|
| DT/OT II | 10 | 11 | 14 | 10 | 11 | 14 |
| DT/OT III | 11 | 13 | 17 | 11 | 14 | 19 |
| Full Production | 11 | 13 | 17 | 11 | 14 | 19 |

[a]For KE and CE rounds only.

[b]Schedule values represent increases (Δ) in time over the current XM1/105mm program.

# ANNEX A

# CANNON COST/SCHEDULE UNCERTAINTY ANALYSIS

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## ANNEX A

## CANNON COST/SCHEDULE UNCERTAINTY ANALYSIS

This analysis examines the cost and schedule uncertainties of the US cannon production of both the United Kingdom 110mm and the Federal Republic of Germany 120mm armament systems.

1. Assumptions:

a. Program will start 3rd Qtr FY76.

b. Existing cannon configuration will be used.

c. Selected cannon has met requirements of DT I and is ready for Development.

d. Six months after start date, manufacturing release (agreement) will be received from UK or FRG.

e. Development phase will consist of:

(1) Review and Conversion of drawings.

(2) Minor changes only.

(3) Checking of fatigue and wear.

(4) Preliminary fatigue/wear data will be available.

(5) Planning of same time frame and quantity of weapons to support XM-1 DT II program.

f. There will be approximately 125 component drawings per weapon.

g. Major forging physicals are the same.

h. Based on preliminary date, both weapons have approximately the same weight, size and length.

i. Off shore-buy weapons will be available for analysis and firing evaluation w/recoil mount and rounds.

j. Producibility, Engineering, and Planning (PEP) will occur during an 18 month duration; complete TDP, including only minor changes, is required.

k. The TDP received will include development manufacturing drawings only, i.e., there will be no tool or gage design drawings, inspection procedures or oomponent routing sheets.

2. Activity Rationale: The Cannon Program network is presented as Figure A-2 of ANNEX A. Following is a description of the program activities:

| Activity No. | |
|---|---|
| 2 | Procure Forgings - Thirty tube forgings and twenty-one breech ring and breechblock forgings will be procured. This quantity will be sufficient to satisfy both the XM-1 and developers' requirements through DT/OT II. Time and cost is based on experience gained on similar cannon size and quantity procurement actions. |
| 3, 4 & 5 | Drawing Translation, Conversion and Material - These activities will cover the necessary conversion of the cannon drawing set for US manufacture. |
| 7 | Off-Shore Buy - One cannon, recoil mechanism and 100 rounds of slug ammunition is required by Watervliet (WVA) to confirm drawings received and to conduct preliminary and comparison firing tests. The time of one year to obtain this material is a judgment and may be reduced through negotiations of higher headquarters. Cost of this material has not been included. |
| 8 | Prepare Drawings - A complete set of US manufacturing drawings will be prepared. |
| 9 | Manufacture Cannon and Dynamic Hardware - Two cannons, one for Picatinny Arsenal (PTA) and one for Watervliet, plus one dynamic test specimen, will be fabricated from the US-converted drawings. Fabrication time and cost estimates are based on experience gained on similar configuration cannon. |
| | The following three test activities have been divided into two phases with an estimated risk assigned on success or failure. Dividing the tests allows early evaluation of test results and permits redesign early in the development cycle. |
| 11 & 18 | PTA-FFA Firing Tests - This activity is included only to indicate that firing data generated by PTA and Frankford Arsenal (FFA), including cannon incidents or failures, will be reported to Watervliet. |
| 12 & 19 | Watervliet Firing Tests - Conduct a 300-round test on the US-produced cannon to evaluate performance and function plus a comparison firing with the off-shore buy cannon. |

| Activity No. | |
|---|---|
| 13 & 20 | Dynamic Test - Perform a laboratory dynamic pressure test to determine preliminary breechblock, ring, and tube fatigue life. Establish areas of pressure components to be redesigned to increase fatigue life. |
| 15 & 17 | Redesign and Retrofit - This redesign consists of minor changes and retrofit of the test cannon and confirms the design change with a retest. |
| 22 | Redesign - This redesign activity carries a high risk, i.e., at this time in the development program the redesign necessary to correct the deficiency has to be minor; if it's major, it will take longer than the estimated activity time and will cause a termination of the program or return to start. |
| 24 | Manufacturing Cannons and Spare Tubes - The required quantity of cannons and spare tubes to support the XM-1 vehicle will be manufactured and delivered as indicated. |
| 25 | Manufacturing PA and Watervliet Cannons - Three cannons plus spare tubes, to the same configuration as the XM-1 hardware, will be fabricated--one for PTA and two for WVA. |
| 27 | Firing Test - This test will be to evaluate the final design configuration of the cannon; 500-slug rounds will be fired to evaluate the following:<br><br>Breech function and performance<br>Bore evacuator performance<br>Tube and breech strain vs. pressure/time<br>System accelerations<br>Tube bore firing damage (heat checking)<br>Movie coverage |
| 30 & 31 | Redesign Retrofit - Again during Watervliet's test program a redesign and retrofit activity has been identified to allow for minor design changes that may be required to be incorporated into the XM-1 cannons prior to or during DT II. |
| 33 | Test Lead Time - This activity is included to provide the necessary cannon/vehicle assembly lead time prior to vehicle delivery, i.e., from delivery of first two cannons to initiation of DT II is six months. |
| 35 | Manufacturing Dynamic Hardware - Six breech mechanisms with stub tubes and fixtures will be fabricated to provide the required quantity of dynamic fatigue samples. |

| Activity No. | |
|---|---|
| 36 | Dynamic Test - This test, to be conducted by Watervliet Research Lab., will determine and confirm the safe breech ring and breechblock fatigue life. The established safe life value is required prior to or during OT II to provide an interim safety release for crew firing. |
| 39 & 40 | Producibility Engineering and Planning (PEP) - This activity is a normal PEP program to take the cannon development drawings and produce the necessary soft wear and drawings for production or a complete Tech Data Package (TDP). |
| 41 | IPF - This activity provides for the initiation of the long lead tooling, gages, etc. associated with Initial Production Facilities (IPF). |

All engineering support activities covers the following normal support:

Program engineering support
Manufacturing support
Test support
Supervision and administration
Maintenance of drawings

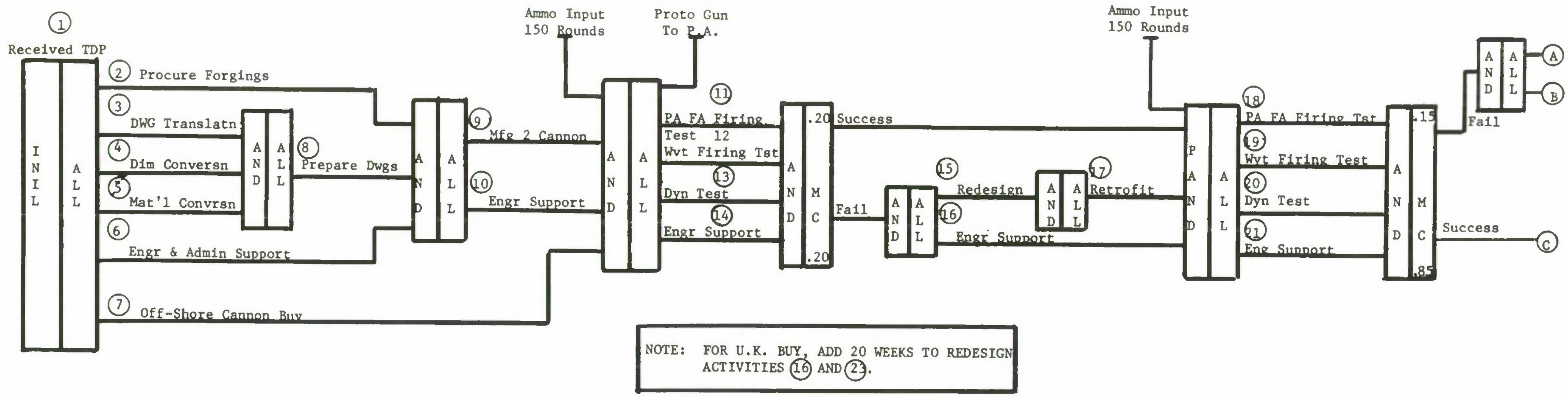


Figure A-2. Development Program for the UK 110MM or the FRG 120MM Cannons. (1 of 2)



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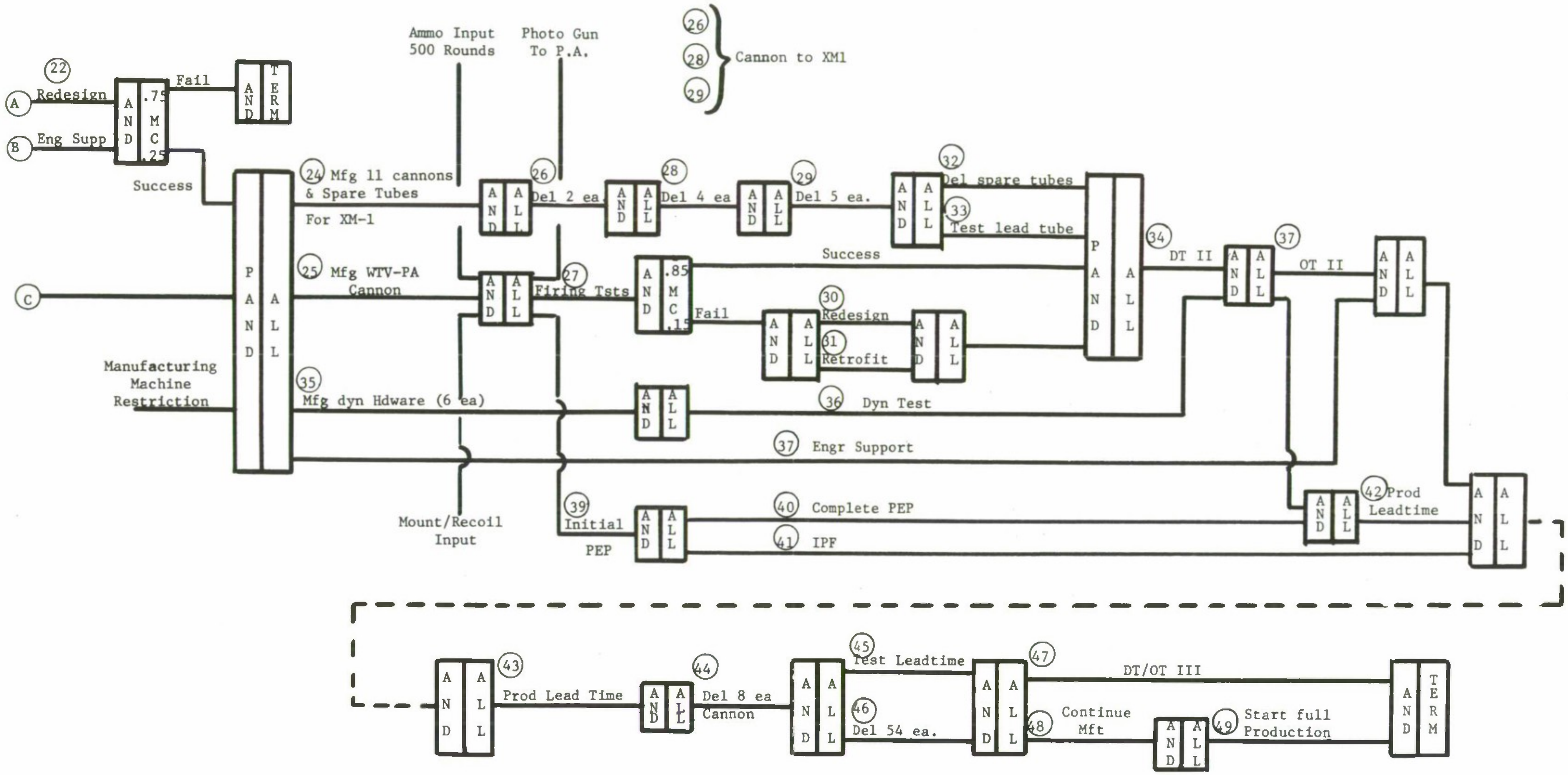


Figure A-2. Development Program for the UK 110MM or the FRG 120MM Cannons. (2 of 2)



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ANNEX B

PROJECTILE SHELL METAL PARTS
COST/SCHEDULE UNCERTAINTY ANALYSIS OBJECTIVE

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## ANNEX B

## PROJECTILE SHELL METAL PARTS COST/SCHEDULE UNCERTAINTY ANALYSIS

### OBJECTIVE

This analysis examines the cost and schedule uncertainties of U.S. production of both the United Kingdom (UK) 110mm and the Federal Republic of Germany (FRG) 120mm K. E. projectile shell metal parts.

### BACKGROUND

Presently, the U.S. Army is participating in the Tripartite Tank Armament Study with the United Kingdom and the Federal Republic of Germany concerning performance and cost effectiveness among three candidate tank weapon systems. These systems are the US 105mm cannon and associate projectiles, the UK 110mm system, and the FRG 120mm system.

In June 1974, the ARMCOM Systems Analysis Office (AMSAR-SAS) requested the Systems Analysis Division, Frankford Arsenal (SARFA-PAS) to initiate a Decision Risk Analysis in support of the Tripartite Tank Armament Study. Our risk analysis was to examine the cost and schedule uncertainties of U.S. production of projectile shell metal parts from the foreign technical data packages of the UK 110mm and FRG 120mm weapon systems.

In October 1974, a SARFA-PAS interim risk analysis report, as requested by AMSAR-SAS, was forwarded to both AMSAR-SAS and Plans and Analysis Office, Picatinny Arsenal (SARPA-PA-S) for inclusion into their consequential studies. The interim analysis was based upon data on the above foreign weapons sytems then available to FFA engineers. Assessments made by the FFA Artillery Ammunition Production Office concerning materials order lead time, fabrication, and production costs and schedules reflected subjective estimates based upon the production of 3500 projectiles.

Subsequent program actions indicate that approximately 5000 projectiles need be fabricated, 1900 of which are for testing on the XM1 tank. To ascertain the effects on scheduling and costs due to the increased production quantity and to assess the impact of updated information, a revised risk analysis was prepared. This report represents our current penetrator/shell metal parts risk analysis input to the SARFA-PA-S tank ammunition cost/schedule uncertainty analysis as part of the above AMSAR-SAS study.

The penetrator/shell metal parts risk analysis for each foreign system consists of the review of the foreign technical data packages (TDP), the Frankford Arsenal In-House manufacture of proof slugs for initial propellant and weapon testing, the fabrication and assembly of approximately 5000 projectiles, and the testing of the projectiles

through TECOM DT II testing. Figure B-1 (Annex B) reflects the skeleton network.

PROGRAM ASSUMPTIONS

In order to assure a timely production schedule, our engineers have assumed that they will receive the highest possible DA project priority for funds, manpower, and contract award. This assumption underlies all time estimates in the schedule analysis.

The following engineering assumptions as to the character and risk of the program are made:

1. The TDP will arrive at Frankford Arsenal as a workable package with no important problems still to be resolved.

2. No product improvements to the basic TDP will be made during program execution.

3. Proof slugs will be fabricated in-house.

4. All contracts will be given priority in processing and sole source award.

5. Production rates will average approximately 500 projectiles per month.

6. Delivery of production quantities to Picatinny Arsenal for LAP will be made in a continuous manner.

7. Fabrication of 2200 projectiles for confirmatory by FFA, PTA, and WVA will be concurrent with the accuracy/security and penetration testing of the 1st pilot lot.

8. Fabrication of the TECOM quantity of 500 projectiles will be concurrent with Frankford Arsenal testing of rounds from the previous 2200 quantity.

9. The TECOM quantity will be released by Frankford Arsenal upon successful completion of testing in "8" above.

10. Fabrication of approximately 1900 projectiles for testing with the XM1 tank will immediately follow the TECOM quantity and will be concurrent with TECOM testing.

11. A minor failure in the accuracy/security test will imply that the test will be reevaluated.

12. A major failure in the accuracy/security test is assumed to be either a function of material problems or that the foreign designs are not adequate under our testing conditions.

NETWORK RISK ANALYSIS

Figure B-2 is the network used for analyzing both the UK 110mm and FRG 120mm weapon systems penetrator/shell metal parts program. Descriptions of network activities are presented in Table B-1. Table B-2 contains the time and cost data associated with the UK analysis. Table B-3 contains the time and cost data for the analogous FRG analysis. Time data is in the form of triangular distributions. However, arc A62 is in the form of a cumulative density function described by four points. Cost data is either in the form of fixed + variable (dependent upon time) costs or "fixed" costs given in terms of a random variable from distributions having their triangular distributions notated by 3 parameters in parentheses. Some network activity costs are dependent upon costs associated with other activities. A specific occurrence is the cost of remanufacturing items. The assumption is made that the remanufactured unit costs are equal to the original costs. Therefore, if 5000 items cost $p, a random variable chosen from the estimated cost distribution of ($4000-$5000-$6000), 100 more items would cost ($p/5000) x 100. This type data occurs in Table B-2. (All arcs and nodes not tabulated in Annex Tables B-2 and B-3 are signal arcs used for the network logic).

Major milestone activities, resulting from the network analysis, which must interface with the propellant risk analysis milestones of Picatinny are summarized in Table B-4. Based upon the assumption that all inputs needed by Frankford Arsenal are available, as required, the minimum time period to a final Frankford Arsenal-produced TDP for the UK 110mm is approximately 26 months, the mean time is 36 months, and the 80% certainty time is 37 months. Similarly, for the FRG 120mm, the minimum time is 26 months, the mean time is 41 months, and the 80% certainty time is 43 months.

CONCLUSIONS

For US production of projectiles for the UK 110mm weapon system, Frankford Arsenal estimates with 80% certainty that the 1st partial delivery of projectiles can be made within 19 months from receipt of the foreign TDP. The initial delivery of projectiles from the XM1 quantity of 1900 for LAP will be concurrent with TECOM testing. With a production rate of approximately 500 units per month, FFA estimates with probability of 0.8 that safety certification will be passed and fabrication of the total XM1 quantity will be complete within 30 months from receipt of the foreign TDP.

Similarly, 1st partial delivery of US produced FRG projectiles can be made within 25 months, estimated with 80% certainty. Safety certification should be passed and fabrication of the total XM1 quantity complete within 37 months on an 80% surety level.

Costs, similar for both programs, are less than $7.5 million dollars on the 80% certainty level; the mean cost is $7.1M. The probability of success is in excess of 0.98.

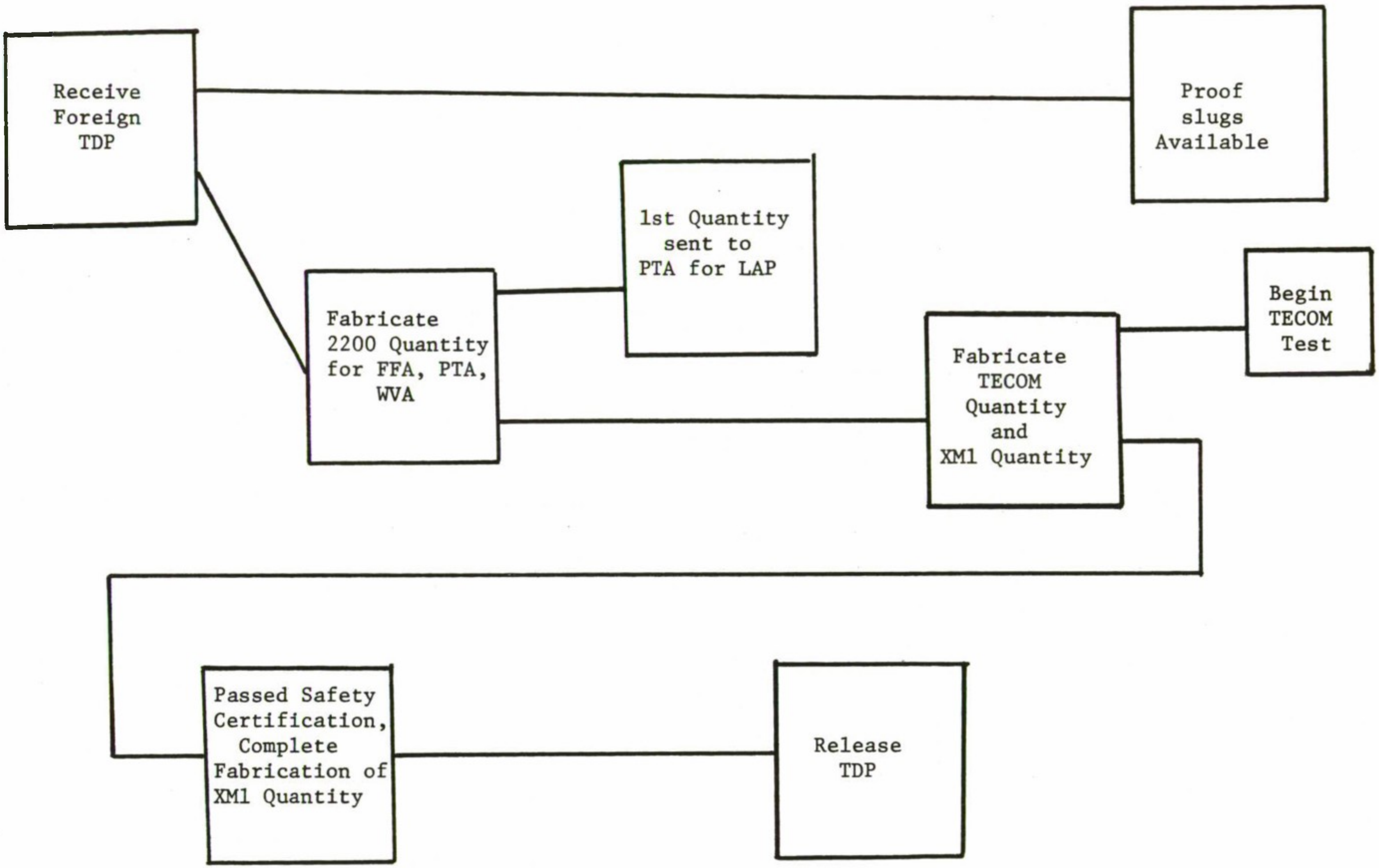


Figure B-1. Tripartite Tank Armament Program -- Penetrator/Metal Parts -- Frankford Arsenal

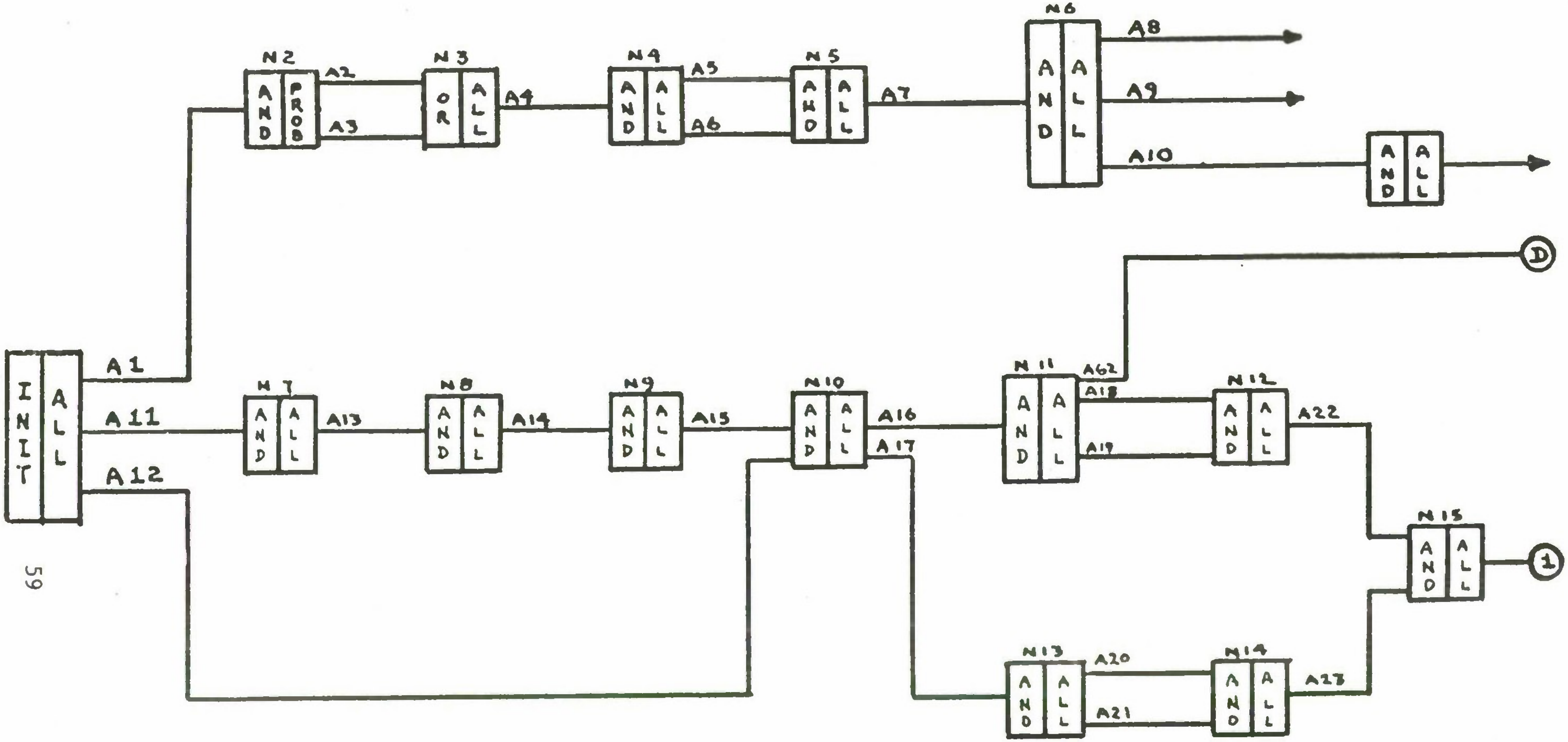


Figure B-2. Projectile Shell Metal Parts Network (1 of 5)

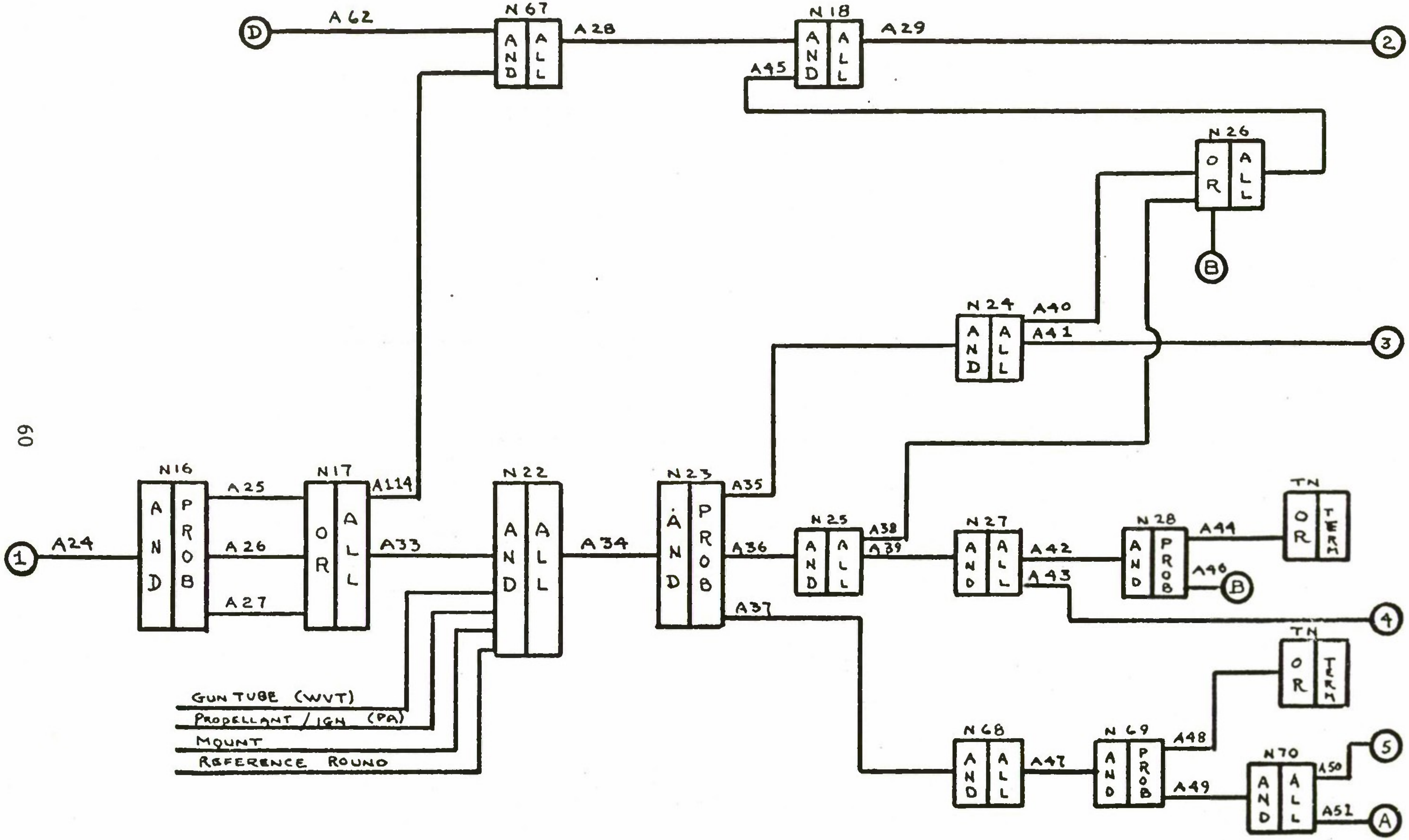


Figure B-2. Projectile Shell Metal Parts Network (2 of 5)

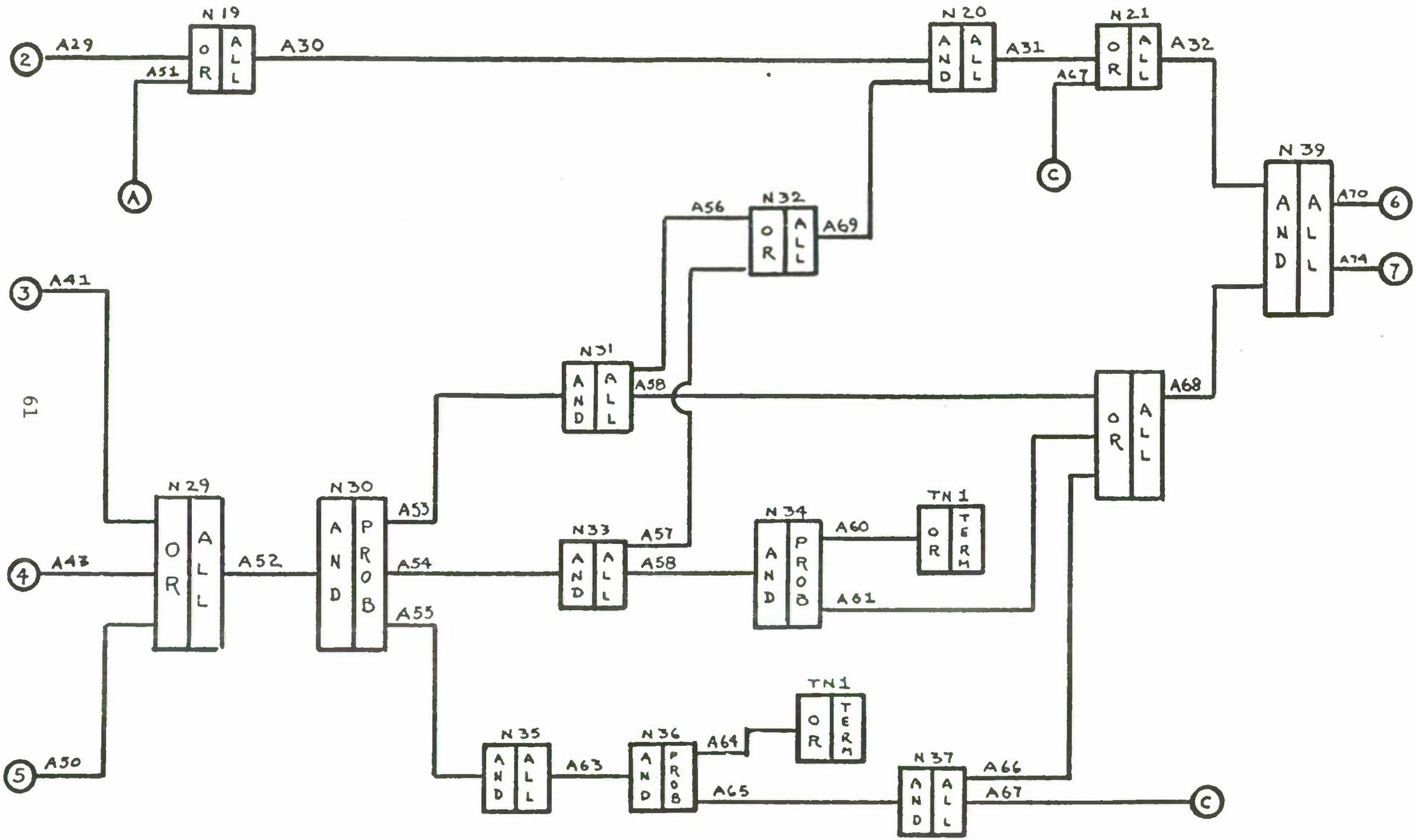


Figure B-2. Projectile Shell Metal Parts Network (3 of 5)

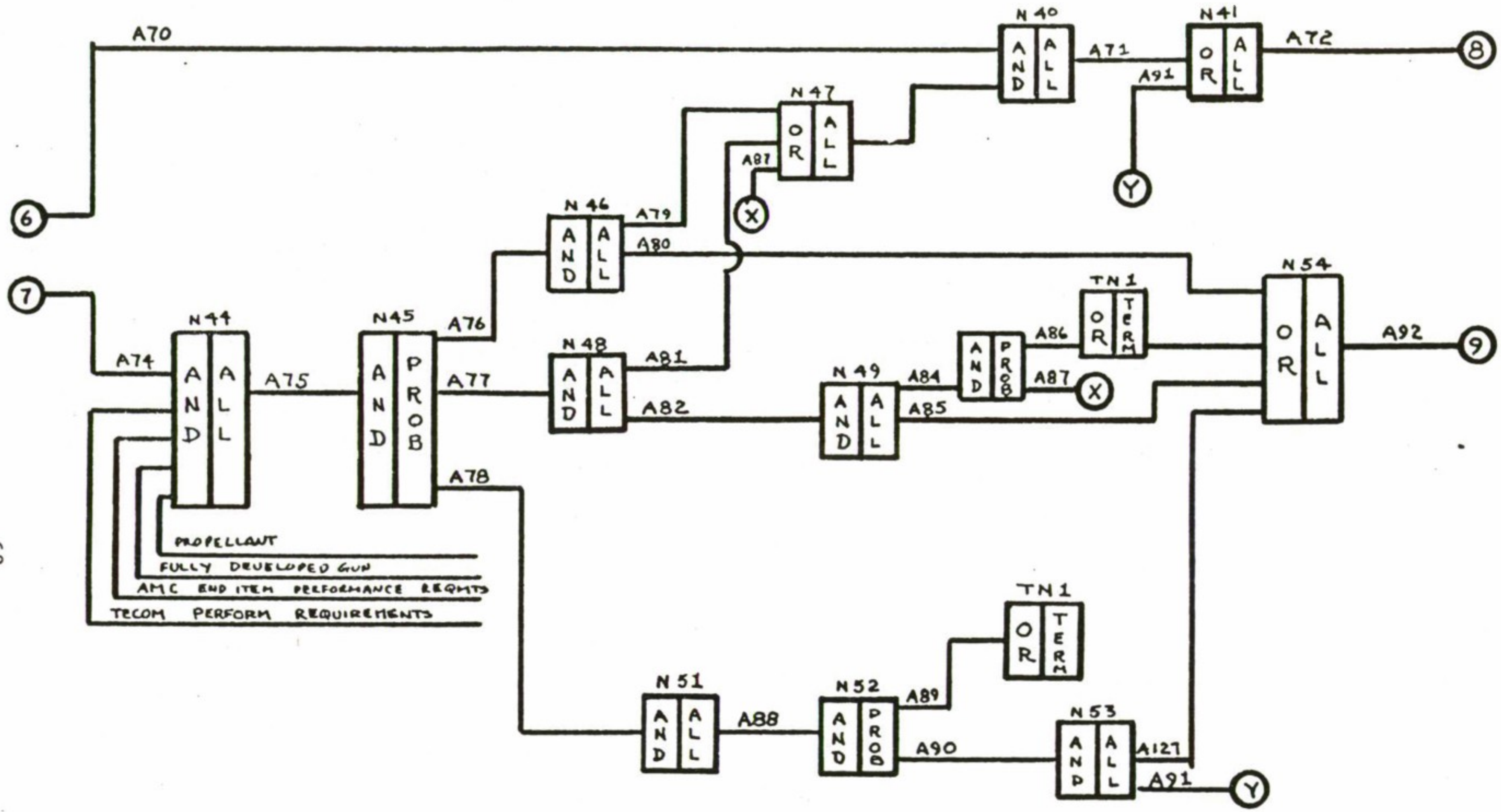


Figure B-2. Projectile Shell Metal Parts Network (4 of 5)

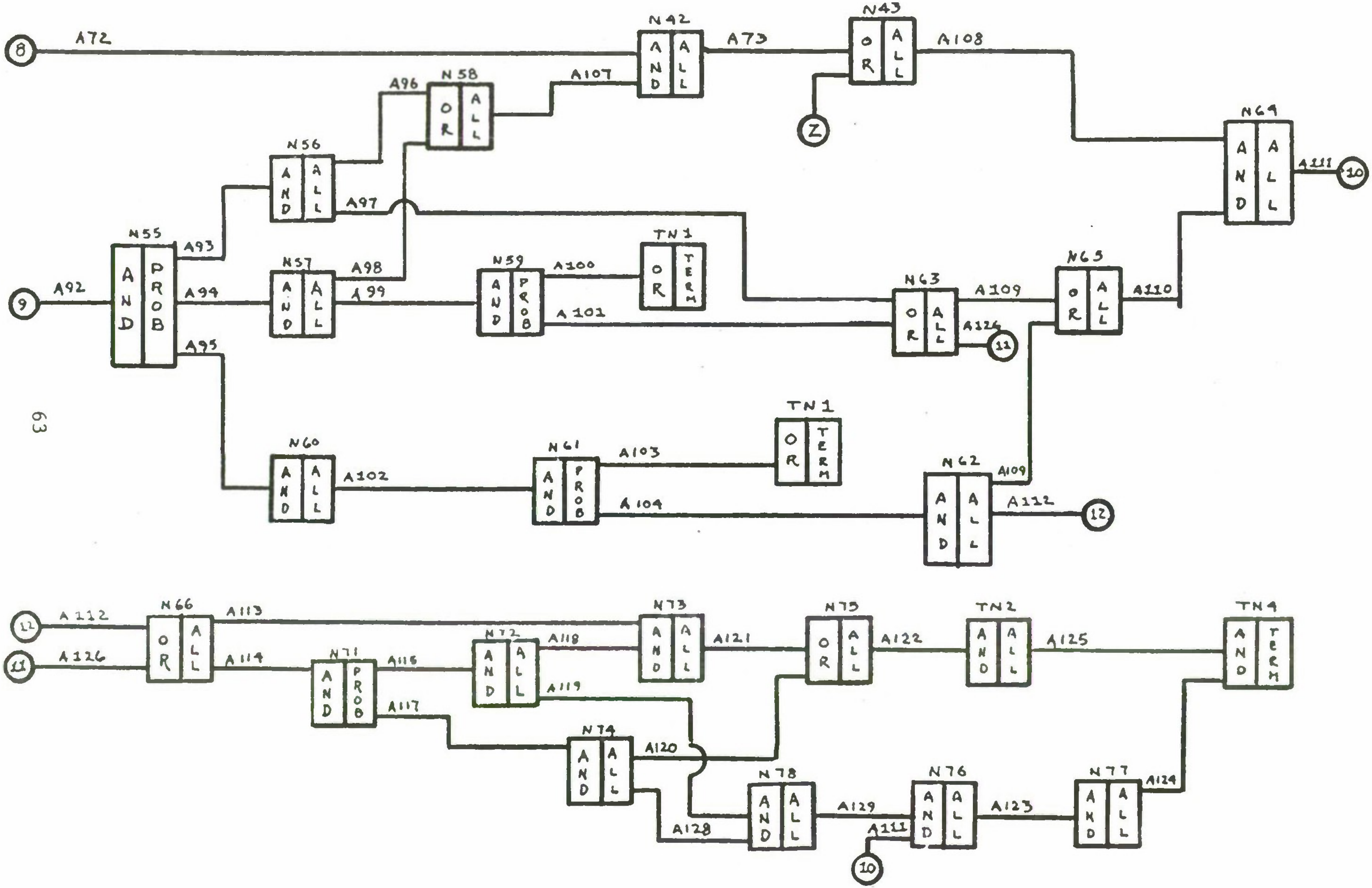


Figure B-2. Projectile Shell Metal Parts Network (5 of 5)

TABLE B-1. PROJECTILE SHELL METAL PARTS NETWORK ACTIVITY DESCRIPTION

| Arc Number | Description |
|---|---|
| A1 | Review TDP for slugs |
| A2 | Translate drawings |
| A3 | Generate design drawings |
| A4 | Preliminary methodizing in house |
| A5 | Continue methodizing |
| A6 | Order materials |
| A7 | Fabricate & assemble initial quantity |
| A8 | Proof slugs to WVA |
| A9 | 1st quantity proof slugs to PTA |
| A10 | Fabricate and assemble final slug quantity for PTA |
| A11 | Make foreign TDP into US TDP and prepare scope of work |
| A12 | Review TDP - material char. & dim. analysis |
| A13 | Contractor plan |
| A14 | Negotiate and evaluate bids |
| A15 | Award contract |
| A16 | Metal parts preliminary methodizing |
| A17 | Penetrator preliminary methodizing |
| A18 | Continue methodizing |
| A19 | Order materials |
| A20 | Continue methodizing |
| A21 | Receive material |
| A22 | Fabricate |
| A23 | Fabricate |
| A24 | Assemble and inpsect |
| A25 | Fail - mech. prob. |
| A26 | Fail - dim. prob. |
| A27 | Pass |
| A28 | Fabricate & assemble proof slugs |
| A29 thru A33 | Signal arcs |
| A34 | Accuracy & security tests |
| A35 | Pass |

TABLE B-1. PROJECTILE SHELL METAL PARTS NETWORK ACTIVITY DESCRIPTION (CONT)

| Arc Number | Description |
|---|---|
| A36 | Minor failure |
| A37 | Major failure |
| A38 | Signal arc |
| A39 | Reevaluate test |
| A40 | Signal arc |
| A41 | Signal arc |
| A42 | Retest |
| A43 | Signal arc |
| A44 | Fail |
| A46 | Pass |
| A47 | Accuracy & security retest |
| A48 | Fail |
| A49 | Pass |
| A50 | Signal arc |
| A51 | Refabricate rounds |
| A52 | Penetration test |
| A53 | Pass |
| A54 | Minor failure |
| A55 | Major failure |
| A56 thru A58 | Signal arcs |
| A59 | Retest |
| A60 | Fail |
| A61 | Pass |
| A62 | Penetrator test |
| A64 | Fail |
| A65 | Pass |
| A66 | Signal arc |
| A67 | Refabricate rounds |
| A68, A69 | Signal arcs |
| A70 | Fabricate rounds for TECOM & XM1 |
| A71 thru A73 | Signal arcs |
| A74 | FFA design test |
| A75 | Accuracy/security test |

TABLE B-1. PROJECTILE SHELL METAL PARTS NETWORK ACTIVITY DESCRIPTION (CONT)

| Arc Number | Description |
|---|---|
| A76 | Pass |
| A77 | Minor failure |
| A78 | Major failure |
| A79 thru A81 | Signal arcs |
| A82 | Reevaluate test |
| A83 | Signal arc |
| A84 | Retest |
| A85 | Signal arc |
| A86 | Fail |
| A87 | Pass |
| A88 | Accuracy/security retest |
| A89 | Fail |
| A90 | Pass |
| A91 | Refabricate 4600 projectile |
| A92 | Penetration test |
| A93 | Pass |
| A94 | Minor failure |
| A95 | Major failure |
| A96 thru A98 | Signal arcs |
| A99 | Retest |
| A100 | Fail |
| A101 | Pass |
| A102 | Penetration retest |
| A103 | Fail |
| A104 | Pass |
| A105 | Signal arc |
| A106 | Replace core 2400 quantity |
| A107 thru A112 | Signal arcs |
| A113 | Full test |
| A114 | Safety certification |
| A115 | Pass |
| A116 | Signal arc |
| A117 | Rebuild 2400 + 10% |

TABLE B-1. PROJECTILE SHELL METAL PARTS NETWORK ACTIVITY DESCRIPTION (CONT)

| Arc Number | Description |
|---|---|
| A118 thru A125 | Signal arcs |
| A122 | Release TDP & TC action |

TABLE B-2. PROJECTILE SHELL METAL PARTS NETWORK
ACTIVITY TIME AND COST FOR THE UK-KE ROUND

| ARC | PROB | TIME (months) | COST (SK) fixed + variable |
|---|---|---|---|
| A1 | | .25-.25-.5 | 8t |
| A2 | .75 | .25-.5-.5 | 12t |
| A3 | .25 | .5-.5-1 | 12t |
| A4 | | .25-.5-.5 | (600-675-750) + 10t |
| A5 | | 4-5-9 | 150 + 2t |
| A6 | | 1-4-9 | 2t |
| A7 | | 2-3-3 | 4t |
| A10 | | 1-2-2 | 4t |
| A11 | | 3-3-4 | 36t |
| A12 | | 1-1.5-2 | 18 + 12t |
| A13 | | 1-1.5-2 | 4t |
| A14 | | 1-2-2 | 4t |
| A15 | | 0 | (4000-5000-6000) = P |
| A16 | | .5-.5-.75 | 2t |
| A17 | | .5-.5-.75 | 2t |
| A18 | | 4-6-6 | 405 + 2t |
| A20 | | 2-4-6 | 150 + 2t |
| A21 | | 0-1-3 | 2t |
| A22 | | 1-1.5-2 | 8t |
| A23 | | 1-1.5-2 | 4t |
| A24 | | 1-1-2 | 15 + 12t |
| A25 | .03 | 4-5-6 | 4t |
| A26 | .07 | 1-1-2 | 4t |
| A27 | .9 | | |
| A62 | | $P(t<3) = 0$ | |
| | | $P(t<6) = .6$ | |
| | | $P(t<7) = .9$ | |
| | | $P(t<10) = 1$ | |
| A28 | | 5-6-9 | 4t |
| A34 | | 1-1.5-2 | 27 + 4t |
| A35 | .9 | | |
| A36 | .09 | | |
| A37 | .01 | 5-6-7 | (Px100/5000) + 8t |
| A39 | | .5-.5-.75 | 8t |
| A42 | | 1-1.5-2 | 27 + 4t |
| A44 | .05 | | |
| A46 | .95 | | |
| A47 | | 1-1.5-2 | 27 + 8t |
| A48 | .05 | | |
| A49 | .95 | | |
| A51 | | 7-9-12 | 30 + 4t |
| A52 | | .5-.5-.75 | 38 + 4t |
| A53 | .9 | | |
| A54 | .09 | | |
| A55 | .01 | 5-6-7 | (P x 30/5000) + 8t |
| A59 | | .5-.5-.75 | 8 + 8t |
| A60 | .05 | | |

TABLE B-2. (CONT)

| ARC | PROB | TIME (months) | COST (SK) fixed + variable |
|---|---|---|---|
| A61 | .95 | | |
| A63 | | .5-.5-.75 | 8 + 8t |
| A64 | .05 | | |
| A65 | .95 | | |
| A67 | | 4-6-9 | 125 + 4t |
| A70 | | 5-5-8 | 4 t |
| A75 | | 1.25-1.75-2.25 | 66 + 4t |
| A76 | .9 | | |
| A77 | .09 | | |
| A78 | .01 | 5-6-7 | (Px300/5000) + 8t |
| A82 | | .5-.5-.75 | 8t |
| A84 | | 1.25-1.75-2.25 | 66 + 8t |
| A86 | .05 | | |
| A87 | .95 | | |
| A88 | | 1.25-1.75-2.25 | 66 + 8t |
| A89 | .05 | | |
| A90 | .95 | | |
| A91 | | 10 + 12 + 15 | 30 + P + 4t |
| A92 | | 1.25-1.5-1.75 | 24 + 4t |
| A93 | .9 | | |
| A94 | .09 | | |
| A95 | .01 | 5-6-7 | (P x 45/5000) + 8t |
| A99 | | 1.25-1.5-1.75 | 24 + 8t |
| A100 | .05 | | |
| A101 | .95 | | |
| A102 | | 1.25-1.5-1.75 | 24 + 8t |
| A103 | .05 | | |
| A104 | .95 | | |
| A106 | | 6-8-11 | (P x 2400/5000) + 4t |
| A66 | | 2-2-2 | |
| A112 | | 2-2-2 | 500 rds if 6 mos.<br>1500 rds if 9 mos.<br>+ 4t |
| A113 | | 4-6-8 | 4t |
| A114 | | 2-3-4 | |
| A117 | | 3-3-4 | 5 + 8t |
| A122 | | 7-9-11 | (Px 2400/5000) + 4t |

TABLE B-3. PROJECTILE SHELL METAL PARTS NETWORK ACTIVITY TIME AND COST FOR THE FRG-KE ROUND[a]

| ARC | PROB | TIME (months) | COST (SK) fixed + variable |
|---|---|---|---|
| A1 | | .5-1-1.5 | 8t |
| A2 | .5 | .25-.5-.5 | 12t |
| A3 | .5 | .5-.5-1 | 12t |
| A5 | | 5-6-10 | 150 + 2t |
| A11 | | 3-4-6 | 36t |
| A12 | | 1-1.5-2 | 18 + 12t |
| A13 | | 1-3-6 | 4t |
| A18 | | 4-7-8 | 405 + 2t |
| A20 | | 2-5-6 | 150 + 2t |
| A25 | .1 | 4-5-6 | 4t |
| A26 | .1 | 1-1-2 | 4t |
| A27 | .8 | | |
| A35 | .85 | | |
| A36 | .10 | | |
| A37 | .05 | 5-6-7 | (P x 100/5000) - 8t |
| A53 | .85 | | |
| A54 | .10 | | |
| A55 | .05 | 5-6-7 | (P x 30/5000) - 8t |

[a]For Arcs A56 through A122 see Table B-2.

TABLE B-4. TRIPARTITE TANK ARMAMENT PROGRAM - FRANKFORD ARSENAL

PENETRATOR/METAL PARTS

(4570 Projectiles)

| | TIME (MONTHS) | | | | | |
|---|---|---|---|---|---|---|
| | UK | | | FRG | | |
| ACTIVITY | OPT | MEAN | 80% | OPT | MEAN | 80% |
| 1st Proof Slugs Available | 7 | 10.2 | 11.2 | 8.5 | 11.7 | 12.7 |
| Ready to Fabricate 2200 Quantity | 11.5 | 15.5 | 16 | 11.5 | 19.4 | 21.2 |
| 1st Quantity of 500 sent to PTA | 13 | 18 | 18.3 | 13 | 22.6 | 24.5 |
| Ready to Fabricate TECOM and XM1 Quantity | 16.5 | 22.4 | 23.5 | 16.5 | 27.3 | 29.4 |
| Ready for TECOM Test (Includes LAP) | 19 | 26 | 27 | 19 | 31 | 33 |
| Safety Certification Passed and Fabrication of XM1 Quantity Complete | 21.5 | 29.4 | 30 | 21.5 | 34.3 | 37 |
| Release TDP | 26 | 35.5 | 37 | 26 | 40.3 | 43 |

| | DOLLARS ($\bar{M}$) | | | | | |
|---|---|---|---|---|---|---|
| | UK | | | FRG | | |
| COST | OPT | MEAN | 80% | OPT | MEAN | 80% |
| FFA TOTAL | | 7.1 | 7.3 | | 7.1 | 7.5 |

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# ANNEX C

# AMMUNITION COST/SCHEDULE UNCERTAINTY ANALYSIS

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## ANNEX C

## AMMUNITION COST/SCHEDULE UNCERTAINTY ANALYSIS

### PURPOSE

The purpose of this study is to develop a program plan and evaluate cost and schedule uncertainties for the US translation of the United Kingdom's (UK) and Federal Republic of Germany's (FRG) candidates for the armor-piercing, fin-stabalized, discarding sable (APFSDS) round of the new Main Battle Tank.

### GENERAL

Two program plans were developed, one for the FRG round and one for the UK round. The programs were developed, based on past history of translation of foreign munitions and some limited knowledge of the specific design details of each munition. The programs were assembled in network form and estimates of cost, time and success probabilities were gathered. The networks were then computer-simulated in order to determine the cost and time variabilities. The networks are presented in Figure C-1. Activity descriptions, cost and time are presented in Table C-1.

### CONSTRAINTS

The following constraints bound the scope of the network simulations.

a. The translation program will start with receipt of a foreign TDP and end with a round that has passed US qualification tests and a US TDP that is ready for production.

b. No attempt will be made during the translation effort to improve round performance over that of the foreign round. Any such effort that may be required would be done in a subsequent product improvement program.

c. Sufficient rounds will be produced in this translation effort to qualify the round and gun and to supply the XM-1 Project with rounds for their DT II/OT II program.

### ASSUMPTIONS

The following assumptions were made in construction of the network logic and gathering of cost and time data.

a. The foreign TDP to be furnished will be one of a round that has passed the FRG and UK version of our DT II/OT II tests.

b. Any possible problems of proprietary data will be resolved prior to receipt of the TDP.

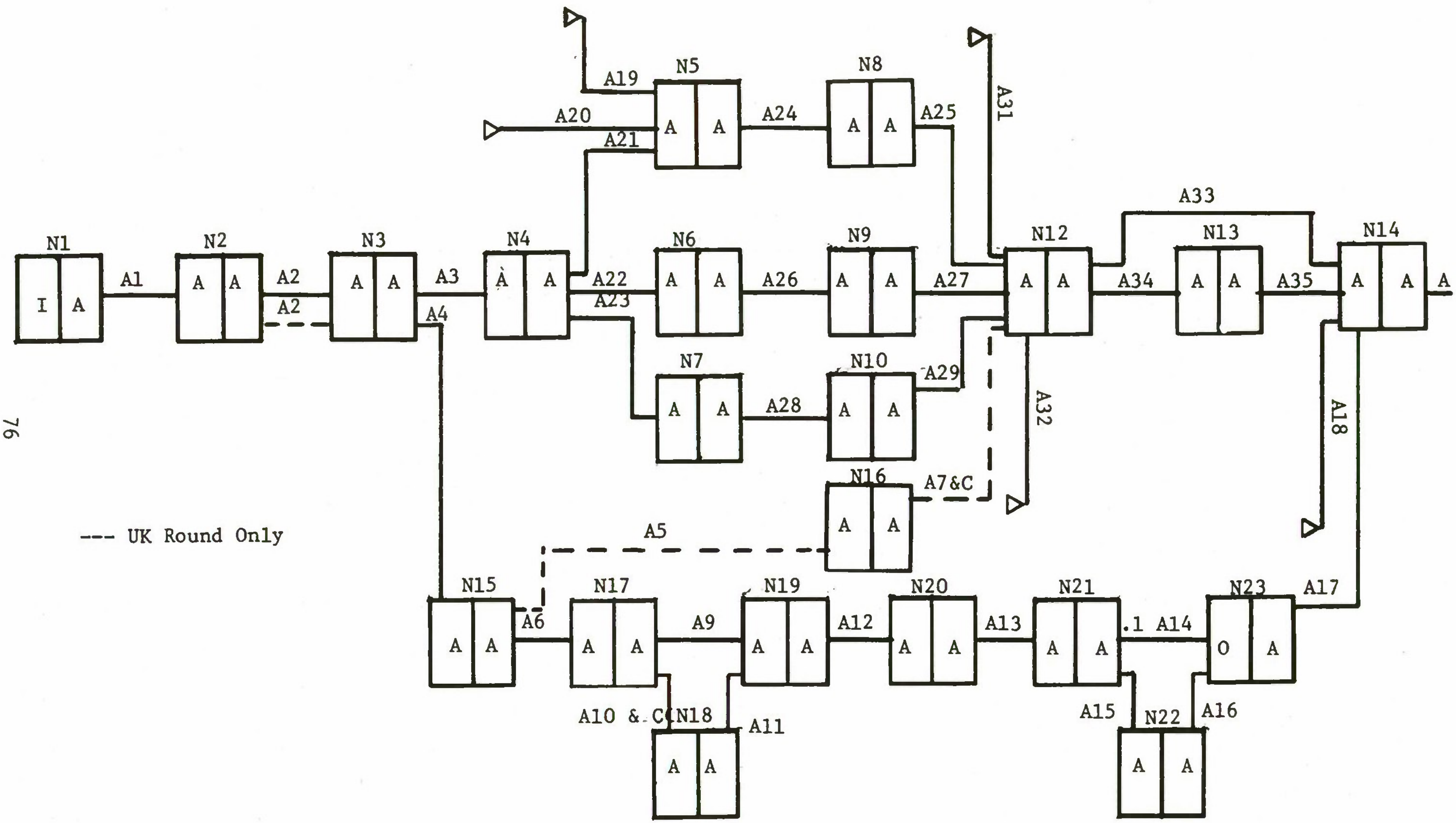


Figure C-1. Ammunition Development Network (1 of 4)

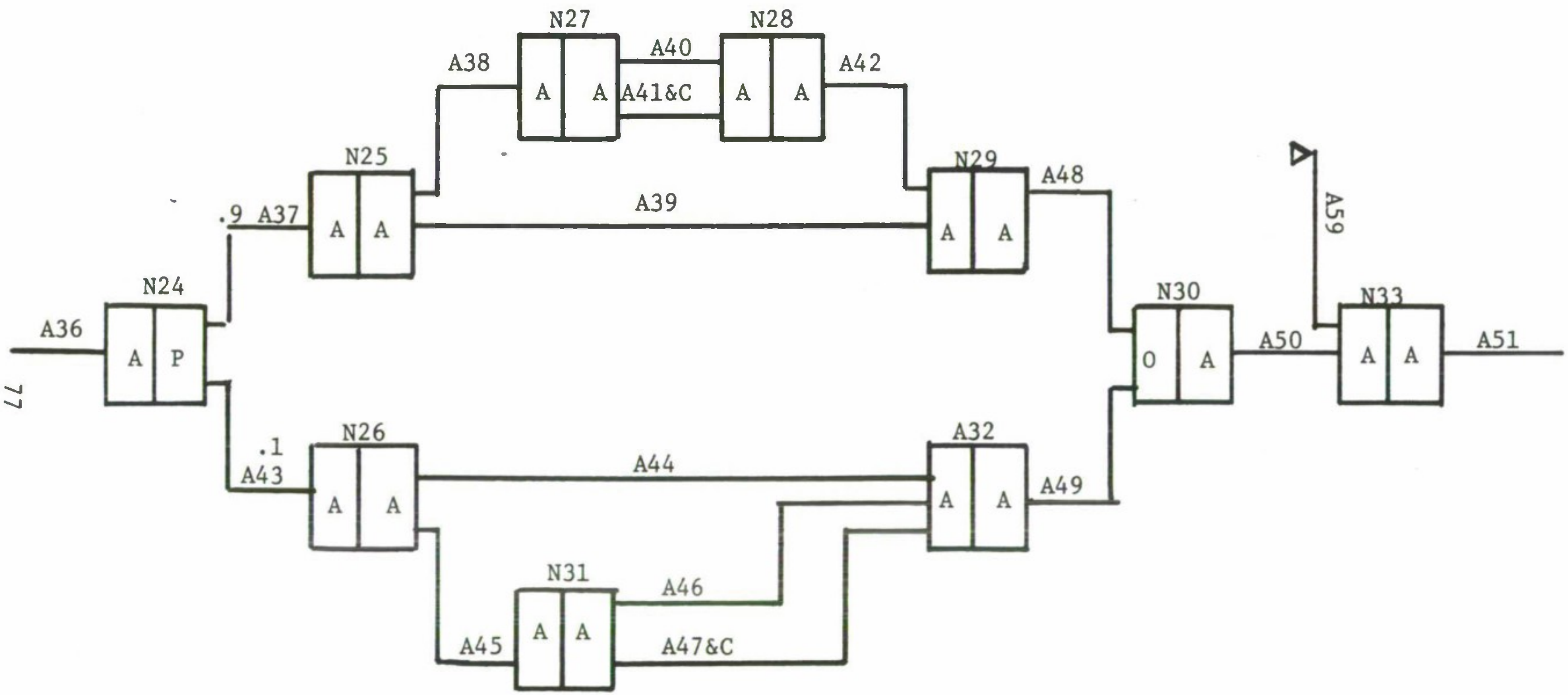


Figure C-1. Ammunition Development Network (2 of 4)

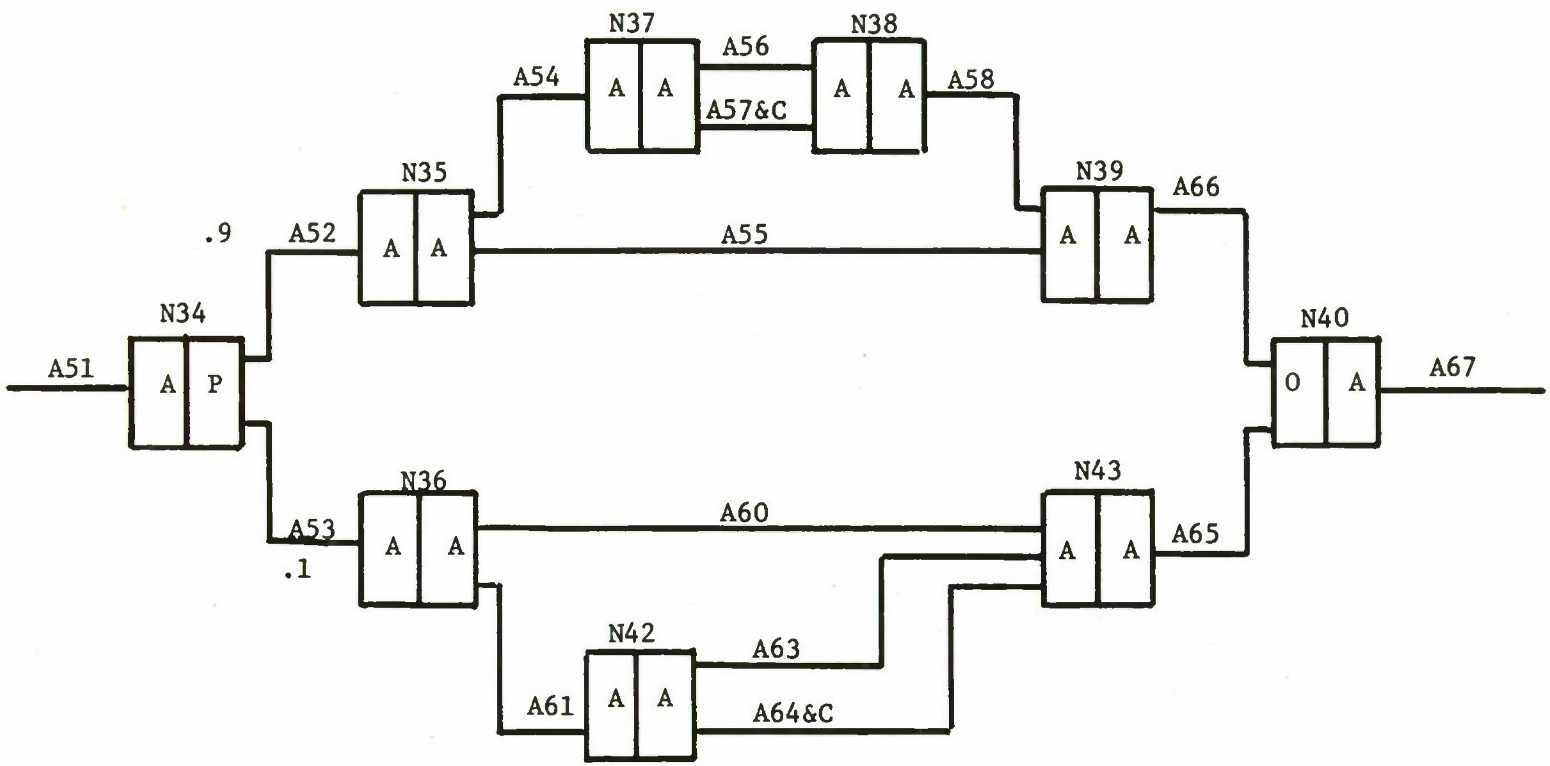


Figure C-1. Ammunition Development Network (3 of 4)

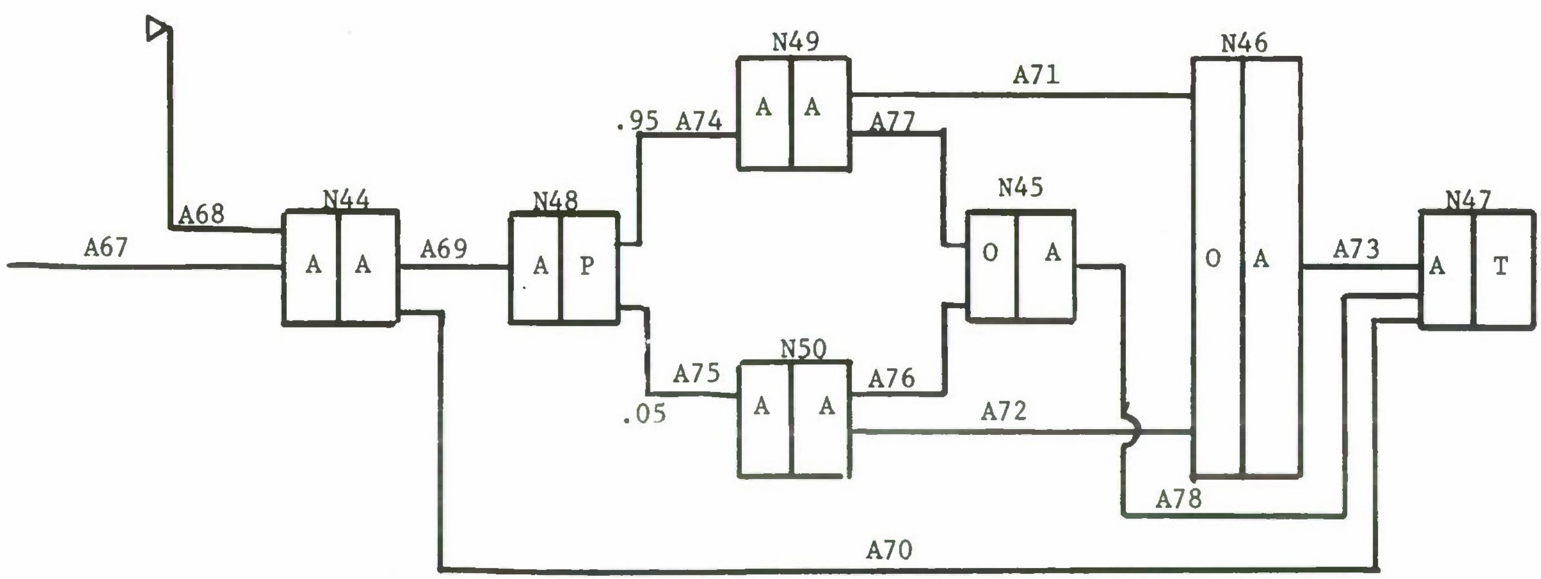


Figure C-1. Ammunition Development Network (4 of 4)

TABLE C-1. ARC DATA FOR FRG AND UK NETWORKS

| Arc Name | Description | Time (Months) | Cost ($K) | | From | To |
|---|---|---|---|---|---|---|
| | | | Fixed | Variable | | |
| A1 | Receive TDP | 0 | 0 | | N1 | N2 |
| A2 | Translate TDP | 1, 2, 3 | 25 | 0 | N2 | N3 |
| *A2 (UK) | Signal | 0 | 0 | | N2 | N3 |
| A3 | Review TDP | 1, 2, 4 | 0 | 8 | N3 | N4 |
| A4 | Stub Case to FA | 0 | 0 | | N3 | N15 |
| *A5 (UK) | Acquire Cases to Modify | 1, 1, 2 | 0 | | N15 | N16 |
| A6 | Review TDP and Initial Setup | 1.5, 2.5, 2.5 | 0 | 5 | N15 | N17 |
| *A7 (UK) | Modify Cases | 2, 3, 4 | 0 | | N16 | N12 |
| *A7C (UK) | Cost | .18, .22, .30 | 0 | 100 | N16 | N12 |
| A8 | Ammo Cases (Off-shore) | - | - | - | - | - |
| A9 | Receive Cost M+1 | 0 | 40 | 0 | N17 | N19 |
| A10 | Fab Tooling | 4, 7, 10 | 0 | 6 | N17 | N18 |
| A10C | Cost | .50, .75, .90 | 0 | 100 | N17 | N18 |
| A11 | Setup Time | 1, 2, 4 | 0 | 12 | N18 | N19 |
| A12 | Fab Pilot Lot (200) | .5, 1, 2 | 0 | 6 | N19 | N20 |
| A12C | Cost | .15, .20, .25 | 0 | 100 | N19 | N20 |

*Pertains to UK network only

TABLE C-1. (CONT)

| Arc Name | Description | Time (Months) | Cost ($K) Fixed | Cost ($K) Variable | From | To |
|---|---|---|---|---|---|---|
| A13 | Inspect | .25, .25, .25 | 0 | 16 | N20 | N21 |
| A14 | Signal (Good) | 0 | 0 | | N21 | N23 |
| A15 | Fail (Identify Prob) | 0, .25, .25 | 0 | 16 | N21 | N22 |
| A16 | Fix | .25, .25, .75 | 0 | 4 | N22 | N23 |
| A17 | Signal | 0 | 0 | | N23 | N14 |
| A18 | Receive 60 Slugs from FA | - | - | - | - | - |
| A19 | Receive One Gun (Off-shore) | - | - | - | - | - |
| A20 | Received 30 Ammo Components (Off-shore) | - | - | - | - | - |
| A21 | Prop Selection | 1, 2, 4 | 0 | 2 | N4 | N5 |
| A22 | Sidewall Contract | 2, 3, 5 | 0 | 6 | N4 | N6 |
| A23 | Mfg Primer | 3, 5, 6 | 32 | 2 | N4 | N7 |
| A24 | Prop Test | 1, 2, 3 | 20 | 4 | N5 | N8 |
| A25 | Prop Mfg and Del | 2, 4, 6 | 75 | 1 | N8 | N12 |
| A26 | Mfg Dies | 4, 5, 7 | 60 | 4 | N6 | N9 |
| A27 | Sidewall Deliver | 1, 1, 1 | 0 | 2 | N9 | N12 |
| A28 | Static Test | 1, 2, 3 | 10 | 2 | N7 | N10 |
| A29 | Primer Deliver | .25, .25, 1 | 0 | 2 | N10 | N12 |

TABLE C-1. (CONT)

| Arc Name | Description | Time (Months) | Cost ($K) Fixed | Cost ($K) Variable | From | To |
|---|---|---|---|---|---|---|
| A31 | Receive 30 Ammo Components Off-shore | - | - | - | - | - |
| A32 | Receive 60 Slugs from FFA | - | - | - | - | - |
| A33 | Mfg Sidewall | 1.5, 2, 3 | 20 | 4 | N12 | N14 |
| A34 | First Prop System Test | 2, 3, 5 | 40K | 2 | N12 | N13 |
| A35 | Signal | 0 | 0 | | N13 | N14 |
| A36 | LAP | 1, 2, 3 | 10K | 10 | N14 | N24 |
| A37 | Signal (Successful Design) | 0 | 0 | | N24 | N25 |
| A38 | Test Results Available | 1/2 A39 | | | N25 | N27 |
| A39 | Second Prop System Test | 1, 2, 4 | 30K | 6 | N25 | N29 |
| A40 | Produce Sidewalls | 1, 2, 3 | 66 | 4 | N27 | N28 |
| A41 | Produce Stub Cases FA | 1, 2, 4 | 0 | 8 | N27 | N28 |
| A41C | Cost | .6, .7, .9 | 0 | 100 | N27 | N28 |
| A42 | Signal | 0 | 0 | | N28 | N29 |
| A43 | Fail (Signal) | .5, 1, 2 | 15K | 6 | N24 | N26 |
| A44 | Fix and Retest | 3, 5, 8 | 40 | 6 | N26 | N32 |
| A45 | Wait for Fix | 1, 2, 3 | 0 | | N26 | N31 |

TABLE C-1. (CONT)

| Arc Name | Description | Time (Months) | Cost ($K) Fixed | Cost ($K) Variable | From | To |
|---|---|---|---|---|---|---|
| A46 | Produce Sidewalls | 1, 2, 3 | 60 | 4 | N31 | N32 |
| A47 | Produce Stub Cases | 1, 2, 4 | 0 | 8 | N31 | N32 |
| A47C | Cost | .6, .7, .9 | 0 | 100 | N31 | N32 |
| A48 | Signal | 0 | 0 | | N29 | N30 |
| A49 | Signal | 0 | 0 | | N32 | N30 |
| A50 | Signal | 0 | 0 | | N30 | N33 |
| A51 | LAP | 1, 2, 3 | 55 | 10 | N33 | N34 |
| A52 | Signal (Success) | 0 | 0 | | N34 | N35 |
| A53 | Fail (Signal) | 1, 1, 2 | 100 | 10 | N34 | N36 |
| A54 | Wait for Results | 1/2 A55 | | | N35 | N37 |
| A55 | FDT | 1.5, 2.5, 4 | 200 | 10 | N35 | N39 |
| A56 | Produce Sidewalls | 1, 2, 3 | 47 | 4 | N37 | N38 |
| A57 | Produce Stub Cases (1500) | 1, 2, 3 | 0 | 8 | N37 | N38 |
| A57C | Cost | .71, .82, 1.0 | 0 | 100 | N37 | N38 |
| A58 | Signal | 0 | 0 | | N38 | N39 |
| A59 | - | - | - | - | - | - |
| A60 | Fix and Retest (FDT) | 3, 5, 8 | 300 | 14 | N36 | N43 |

TABLE C-1. (CONT)

| Arc Name | Description | Time (Months) | Cost ($K) | | From | To |
|---|---|---|---|---|---|---|
| | | | Fixed | Variable | | |
| A61 | Wait for Fix | 1, 2, 3 | 0 | | N36 | N42 |
| A62 | Signal (Prototype to WVT) | - | - | - | - | - |
| A63 | Produce Sidewalls | 1, 2, 3 | 30 | 4 | N42 | N43 |
| A64 | Produce Stub Cases (1000) | 1, 2, 3 | 0 | 8 | N42 | N43 |
| A64C | Cost | .45, .52, .67 | 0 | 100 | N42 | N43 |
| A65 | Signal | 0 | 0 | | N43 | N40 |
| A66 | Signal | 0 | 0 | | N39 | N40 |
| A67 | Signal (FDT Comp) | 0 | 0 | | N40 | N44 |
| A68 | Receive Proj (FFA) | - | - | - | - | - |
| A69 | LAP (DT II) | 1, 1, 3 | 60 | 10 | N44 | N48 |
| A70 | Finalize TDP | 4, 6, 8 | 0 | 12 | N44 | N47 |
| A71 | DT II Success | 4, 6, 8 | 400 | 10 | N49 | N46 |
| A72 | DT II Fail Fix and Retest | 6, 9, 14 | 650 | 14 | N50 | N46 |
| A73 | TC | 2, 3, 6 | 0 | 5 | N46 | N47 |
| A74 | Signal (Success) | 0 | 0 | | N48 | N49 |
| A75 | Signal (Fail) | 0 | 0 | | N48 | N50 |
| A76 | Safety Release | 5, 6, 7 | 0 | | N50 | N45 |

TABLE C-1. (CONT)

| Arc Name | Description | Time (Months) | Cost ($K) Fixed | Cost ($K) Variable | From | To |
|---|---|---|---|---|---|---|
| A77 | Safety Release | 2, 3, 4 | 0 | | N49 | N45 |
| A78 | Signal | 0 | 0 | | N45 | N47 |

c. Foreign hardware will be available in the quantities and at the times needed in the program.

d. Funds will be available on time and will not cause schedule slippages.

e. Testing facilities will be available when needed.

RESULTS

Foreign Hardware Requirements

The programmed network requires inputs of a foreign gun, complete rounds and components. The quantities and time from receipt of TDP for the foreign hardware required by Picatinny Arsenal are shown in Tables C-2 and C-3.

Time

Various milestones were chosen within the programs. The times to reach each milestone from receipt of the TDP are shown in Tables C-4 and C-5. The interval between the five percent and 95 percent column indicates a range in which completion of the milestone will occur 90 percent of the time. The start of DT II is when complete rounds will be available for the XM-1 Project. Safety release is when these rounds may be crew-fired. The resultant times are coordinated with Frankford Arsenal's network for availability of slugs and projectiles.

Cost

The costs shown in the Picatinny Arsenal networks do not include the following items:

1. The cost of any of the foreign hardware requirements.

2. The cost for engineering, testing, and hardware associated with slugs and projectiles.

3. The cost of engineering, testing, and hardware associated with translation of the new gun.

The costs shown in the Picatinny Arsenal networks do include the following:

1. The cost of engineering, testing, and hardware for the translation of the propellant, primer, combustible sidewall, and stub case (FFA input).

2. The cost of LAP for all rounds produced.

TABLE C-2. PICATINNY ARSENAL NEEDS – FRG HARDWARE

| Type of Hardware | Quantity | Time (Mo.) Minimum (5%) | Mean |
|---|---|---|---|
| Gun | 1 | 5.2 | 6.7 |
| Ammo Components | 30 | 5.2 | 6.7 |
| Ammo Components | 30 | 12.5 | 14.1 |
| Stub Cases | 60 | 12.5 | 14.1 |
| Complete Rounds | 30 | 17.7 | 19.6 |
| Complete Rounds | 200 | 23.5 | 26.7 |
| Complete Rounds | 100 | 29.9 | 34.4 |

TABLE C-3. PICATINNY ARSENAL NEEDS – UK HARDWARE

| Type of Hardware | Quantity | Time (Mo.) Minimum (5%) | Mean |
|---|---|---|---|
| Gun | 1 | 3.3 | 4.7 |
| Ammo Components | 30 | 3.3 | 4.7 |
| Ammo Components | 30 | 10.6 | 12.2 |
| Complete Rounds | 30 | 15.7 | 17.6 |
| Complete Rounds | 200 | 21.3 | 23.8 |
| Complete Rounds | 100 | 27.0 | 30.2 |

TABLE C-4. TIME DISTRIBUTIONS TO MILESTONES
(FRG ROUND)

| Milestone | Computer Ref | Time 5% | 95% | Mean |
|---|---|---|---|---|
| 1st Propellant Sys Test | N12 | 12.5 | 15.9 | 14.1 |
| 2nd Propellant Sys Test | N24 | 17.7 | 21.7 | 19.6 |
| Confirmation Test | N34 | 23.5 | 32.0 | 26.7 |
| Start DT II | (Estimated) | 29.9 | 42.3 | 34.4 |
| Complete Safety Rel | N45 | 32.9 | 45.3 | 37.4 |
| TC & Prod. TDP Avail. | N47 | 39.1 | 52.3 | 44.1 |

TABLE C-5. TIME DISTRIBUTIONS TO MILESTONES
(UK ROUND)

| Milestone | Computer Ref | Time 5% | 95% | Mean |
|---|---|---|---|---|
| 1st Propellant Sys Test | N12 | 10.6 | 13.8 | 12.2 |
| 2nd Propellant Sys Test | N24 | 15.7 | 19.7 | 17.6 |
| Confirmation Test | N34 | 21.3 | 27.2 | 23.8 |
| Start DT II | (Estimated) | 27.0 | 35.1 | 30.2 |
| Complete Safety Rel. | N45 | 30.0 | 38.1 | 33.2 |
| TC & Prod. TDP Avail. | N47 | 36.2 | 45.3 | 39.9 |

3. The cost to conduct the combined FFA/PTA confirmation test and DT II.

The cost to conduct the Picatinny Arsenal portion of the translation efforts for the FRG and UK rounds is shown in Tables C-6 and C-7. Total translation can be obtained by summing the costs of the Picatinny, Frankford and Watervliet networks.

The cost distribution is not continuous so two cost ranges are given as well as the overall mean. The first cost range can be expected if no major problems occur and the second if major problems do occur. The probability for being in each range is also given. The complete cost distributions are shown under N47 in the inclosed networks.

TABLE C-6. EXPECTED COST INTERVALS
(FRG Round Translation)

| | Cost Interval ($K) | Probability |
|---|---|---|
| No Major Problem | 1850 - 2000 | .85 |
| Major Problems | 2050 - 2500 | .15 |

Overall Mean Cost - $1,982

TABLE C-7. EXPECTED COST INTERVALS
(UK Round Translation)

| | Cost Interval ($K) | Probability |
|---|---|---|
| No Major Problem | 1868 - 2050 | .86 |
| Major Problems | 2070 - 2500 | .14 |

Overall Mean Cost - $1,984

The cost for translation of the FRG or KE round is shown as being approximately equal. It is expected that as design details of the two rounds become known, more accurate cost estimates can be made and differences will show up.

The cost figures will also vary as a function of the number of rounds produced. A total of 4,570 complete rounds will be produced as part of the translation effort. The cost is represented in Table C-8.

## C-8. EXPECTED COST FOR FRG OR UK ROUND DEVELOPMENT

| | |
|---|---|
| **TRANSLATION EFFORT** | **Quantity** |
| PTA and FFA Testing | 500 |
| WVA Gun Tests | 1500 |
| Complete Round DT II | 500 |
| Subtotal | 2500 |
| **XM-1 PROJECT** | |
| XM-1 Component Acceptance | 200 |
| XM-1 DT II | 1370 |
| XM-1 OT II | 500 |
| Subtotal | 2070 |
| GRAND TOTAL | 4570 |

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